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President's Page

A Home for Planetary Sciences

Prepared by H. E. Newell, Chairman, Planning Committee on Planetary Science, upon invitation of the President, Lloyd V. Berkner

Vannevar Bush has characterized science as "The Endless Frontier." To expand upon this metaphor one can see in science the attack upon a frontier, the pioneering that is analogous to the pioneering and exploration of the hardy frontiersmen of past history. But there is also a phase of science that may be compared with the colonization of new lands. In this phase of science, following upon the opening and initial exploration of the new frontier, the researcher seeks by steady, patient, persistent work to fill in the gaps in measurement and observation not carried out by the frontiersmen who have now moved on to other frontiers. There is always a large part of the body of science in this situation. Spectroscopy has been in, and nuclear research is coming into, such a phase of consolidation. Finally, once the colonization has been achieved, science passes into a period of application, a phase corresponding, in our analogy, to the development of stable political, commercial, and industrial activity. This might be called the engineering phase.

All three phases of scientific activity are essential to a properly balanced and healthy activity. Without the period of consolidation, much of the promise of the frontier work is dissipated. Without the engineering phase, the practical benefits of scientific activities are not developed. Without the continuing attack on new frontiers, science eventually becomes sterile and uninspired.

The new frontier of science in our time is space research. All scientific disciplines will be called upon in its exploration. Hardly a scientific discipline exists that will not benefit from the new knowledge and techniques developed in the exploration of the space frontier.

In the investigation of space, the solar system is an object of primary importance. With the availability of rockets and satellites, the opportunity is opening up for the scientist to study the planets from much the same viewpoint as that from which he has been studying the Earth in the past. Once the property of the astronomer, and not too highly valued a property at that, the planets now are brought within the purview of the geophysicist. It is hoped that the geophysicists and astronomers will unite now to give them the attention that they deserve scientifically.

Our planetary neighbors in the solar system are similar in many respects to our terrestrial home. They are material bodies revolving about the Sun under the influence of the solar radiations and activity. They possess atmospheres which also react to the influence of the Sun as does the Earth's atmosphere. They have doubtless had a history in common with that of the Earth. Their differences from the Earth may by comparison illuminate our study of the Earth itself.

The vehicles with which the planetary frontier is now being opened are the high altitude balloon, the artificial satellite, and the deep-space probe. Already balloon-borne instruments have produced exciting results on radiations from the planets, revealing water as a constituent of the Cytherean atmosphere and detecting radiations possibly from organic materials on Mars. Because of their great expense the satellites and space probes should be used

for those investigations that cannot be carried out by means of the balloons and by means of optical, radio, and radar astronomy on the ground. But it must be clear that there are many such investigations that will require the satellite and space probe. For these, then, it becomes necessary to develop the techniques and instruments needed to carry on the investigations of the planets.

As we undertake the exploration of the Moon and planets with deep-space probes, the opportunity arises for the geophysicist to study these bodies in much the same way that he has been studying the Earth. With the space probe, the Moon and the planets are no longer bodies to be observed at a great distance, but, rather, are new lands open to direct examination and physical exploration. Thus the techniques to be employed are those of the Earth sciences, and not those of astronomy. The new areas of planetary exploration, initially by remote-controlled instruments, and later by teams of trained observers, will utilize many of the techniques already available in the Earth sciences. Instruments have been developed to determine the properties of the Earth, its crust, its interior, its atmosphere, its coupling to the Sun, and its magnetic, gravitational, and electrical fields.

The major experimental problem in the development of instruments for planetary research at this early stage is the adaptation of existing geophysical instruments to the unusual conditions of operation in the environment of the space-flight vehicles or on the unknown terrain of other bodies.

Who, then, are the people to carry out these investigations? It would seem natural to expect that those astronomers who have already been devoting their attention to the planets would continue to do so. In addition, the geophysicists who have the experience required to study and investigate the properties of a planet ought also to join in the investigation of the planets. At the same time, it is quite likely that additional people will be needed to handle the program of planetary studies using satellites and space probes. There is a need, therefore, for educational institutions to develop additional personnel. These scientists should be educated in geophysical sciences with a broad viewpoint to regard the Earth as one of many individuals, to consider all the planets of the solar system as their object of interest.

The question also arises as to the home for the new activity in planetary science. In the days when the planets had to be regarded solely as astronomical bodies, and studied by astronomical techniques alone, it was quite natural to think of this science as belonging under the purview of the American Astronomical Society. Now, however, a number of scientific and professional societies have natural interests in planetary science. The Astronomical Society has an interest on the basis of tradition and the fact that the planets are, indeed, astronomical bodies. The American Rocket Society, and to a lesser extent the American Astronautical Society, might claim purview over this field because of the rocket vehicles to be used in the close exploration of the planets. But, the American Geophysical Union has the strongest interest in this matter. For, as pointed out above, the planets are sisters to the Earth in their relation to the solar system. Techniques and tools that must be used in their continued investigation from both manned and unmanned space vehicles will be the same as, or will derive from, the techniques and tools used in the investigation of the Earth. The great body of individuals with competence in the use of these tools and techniques is to be found in the AGU. Likewise, in the international field, whereas the International Astronomical Union, the International Scientific Radio Union, and the International Astronautical Federation, all have interest of one sort or another in the study of the planets, nevertheless the most natural home would seem to be the International Union of Geodesy and Geophysics.

In view of the importance of planetary science, and the natural place that this field of activity would have in the American Geophysical Union, the President of AGU has created a Planning Committee on Planetary Sciences. As its first action, the Planning Committee sent out a call for contributed papers in planetary science, to be read at the 1960 meeting of the American Geophysical Union. The response was overwhelming, in view of the fact that less than a month was available between the initial call for papers and the final deadline. Approximately 70 papers were submitted and organized into eight sessions by Robert Jastrow and Gordon

J. F. MacDonald, ranging over the fields of Theoretical Physics, Cosmic Rays, Meteorites, Instrumentation for Space Physics, Energetic Particles and Magnetic Fields, Lunar Physics, and Planetary Atmospheres.

The vigor of this response confirmed the soundness of the judgment of the officers of the AGU in establishing Planetary Science as a recognized activity within the Union. It is to be hoped that further activities of the Planning Committee on Planetary Science will provide a continuing forum for the presentation of results in this new area of exciting challenge. Meeting the challenge clearly calls for and deserves vigorous support from the members of AGU.

Scientific Results of Experiments in Space

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This paper presents a brief summary of the scientific results obtained to this date[1] with artificial satellites and deep-space probes (see Tables I, II, III, and IV). Included in this report are a few results obtained with sounding rockets, insofar as they pertain to problems also being investigated with space vehicles. However, no attempt will be made to give equal or extensive coverage to all fields of space science. Also, Russian literature on these problems has not been reviewed as thoroughly as has American literature.

[1] Ed. note: Manuscript dated 5/13/60; received 8/11/60.

It is, of course, impossible to classify the various problems of space science into sharply defined categories. Broadly speaking, and for the purpose of orientation, one might distinguish four different scientific uses of space vehicles, namely (1) to explore the environment of the vehicle itself, that is, of the particles of various kinds and various energies, and the magnetic and electric fields present in the distant regions of space that have now become accessible to direct observation; (2) to obtain further information about our own planet by looking at it from above; (3) to study electromagnetic radiation from celestial sources in the spectral

TABLE I—*U. S. Scientific Satellites*
(from data supplied by the National Aeronautics and Space Administration)

Name	Launch Date	Telemeter Signal Stopped	Orbital Inclination	Perigee Apogee (km)	Instrumentation
Explorer I 1958 α	1 Feb. 1958	28 Feb. 1958	33.2°	356 2546	Geiger counter; Micrometeorite detector
Vanguard I 1958 $\beta 2$	17 Mar. 1958	Still broadcasting	34.3°	650 3964	Beacon
Explorer III 1958 γ	26 Mar. 1958	10 May 1958	33.3°	187 2796	Geiger counter
Explorer IV 1958 ϵ	26 July 1958	19 Sept. 1958	50.3°	263 2213	Geiger counters; Scintillators
Vanguard II 1959 $\alpha 1$	12 Feb. 1959	15 Mar. 1959	32.9°	558 3690	Cloud cover scan
Explorer VI 1959 δ	7 Aug. 1959	9 Oct. 1959	47.0°	252 42,434	Magnetometers; Ion Chamber; VLF Receiver; Geiger counter; Triple coincidence counter system; TV point scanner
Vanguard III 1959 γ	18 Sept. 1959	11 Dec. 1959	33.3°	511 3743	Proton precession magnetometer; Solar x-rays; micrometeorite detector
Explorer VII 1959 $\iota 1$	19 Sept. 1959	Still broadcasting (May 1960)	50.3°	556 1086	Heavy primary cosmic ray counter; Geiger counters; Scintillators; Heat balance experiment; Micrometeorite detector
Tiros I 1960 $\beta 2$	1 Apr. 1960	Still broadcasting (May 1960)	48.41°	690 755	Cloud cover scan

TABLE II—*U.S.S.R. Satellites*
(from data supplied by the National Aeronautics and Space Administration)

Name	Launch Date	Radio Life	Orbital Inclination	Perigee Apogee (km)	Instrumentation
Sputnik I 1957 α	4 Oct. 1957	23 days	65°	228 932	...
Sputnik II 1957 β	3 Nov. 1957	7 days	65°	225 1660	Cosmic rays (Geiger counter); Solar ultra-violet and x-rays; Test animal (Laika)
Sputnik III 1958 $\delta 2$	15 May 1958	over 16 months	51°	226 1880	Heavy primary cosmic rays; Energetic particles; Magnetometer Mass Spectrometer; Micrometeorites; Pressure and density; Positive ion density

TABLE III—*U. S. Space Probes*
(from data supplied by the National Aeronautics and Space Administration)

Name	Launch Date	Maximum Distance of Radio Contact (km)	Instrumentation
Pioneer I	11 Oct. 1958	112,600	Micrometeor detector; Magnetometer; Radiation detector
Pioneer III	6 Dec. 1958	102,000	Radiation detectors
Pioneer IV	3 Mar. 1959	653,000	Radiation Detectors
Pioneer V	11 Mar. 1960	13,450,000 on May 9, 1960	150 watt transmitter; Ionization Chamber; Geiger counter; Magnetometer; Micrometeorite counter

TABLE IV—*U.S.S.R. Space Probes*
(from data supplied by the National Aeronautics and Space Administration)

Name	Launch Date	Orbit	Instrumentation
Lunik I	2 Jan. 1959	In orbit around the Sun	Temperature and pressure inside vehicle; Gas components of interplanetary matter and corpuscular radiation of sun; Magnetic fields of Earth, Moon; Meteorite particles in space; Heavy nuclei in primary cosmic rays
Lunik II	12 Sept. 1959	Lunar impact	Temperature and pressure inside vehicle; Magnetic fields of Earth, Moon; Meteoritic particles; Heavy nuclei in primary cosmic radiation
Lunik III	3 Oct. 1959	Earth-Moon orbit	Two cameras plus associated equipment for processing and transmission

regions where the terrestrial atmosphere or ionosphere have heretofore made observations impossible; and (4) to explore the other planets and the moon.

Taking up the above four items in the reverse order, (3) and (4) can be disposed of briefly because space science has not yet accomplished much in these fields. As to item (4): although Russian scientists have succeeded in taking a picture of the back of the moon, this remarkable technical achievement does not help greatly to solve any of the important problems on the structure and history of the moon. Regarding item (3), a start towards astronomy from outer space has been made by means of rockets. With these devices Dr. Friedman, Dr. Kupperian, and their collaborators have made important observations of the ultra-violet light from the night sky and of the ultra-violet emission as well as the X-ray emission of the sun. To quote one interesting result, they found a strong emission of X rays from solar flares. Several of the Russian and American satellites are equipped with ultra-violet or X-ray detectors, but no results have been made public to this date.

Regarding item 2, which includes geodetic measurements, meteorological observations, top-sounding of the ionosphere, and the like, observations of the trajectories of artificial satellites have already provided a substantial amount of new and important information on the gravitational field of the earth, and, by implication, on the inner structure of the earth itself. The most useful satellite for this purpose has been Vanguard I, launched March 17, 1958, on a 34° orbit, with a perigee height of about 650 km and an apogee height of about 3960 km. From the observational data on the trajectory of this satellite, it has been possible to determine the first five harmonics of the earth's gravitational field; in this country, the analysis has been carried out mostly by a group of scientists from the National Aeronautics and Space Administration (NASA) and the Smithsonian Institution.

As is well known, a fluid or, more realistically, a plastic Earth at rest would acquire a perfectly spherical shape under the influence of its own gravitational field. Under the combined influence of the gravitational forces and of the centrifugal forces, due to its daily rotation, a plastic Earth would acquire the shape of an ellipsoid of revolution, with a fractional difference between the equatorial and the polar axes close to 1/300. The geoid's surface, as determined from the low harmonics which can be obtained from the satellite's orbit, is appreciably different from this theoretical surface. The equatorial bulge is slightly greater than predicated, corresponding to a fractional difference of 1/298 between the axes. Moreover, the presence of a third harmonic tends to give the geoid a slightly pear-shaped figure (Figure 1).

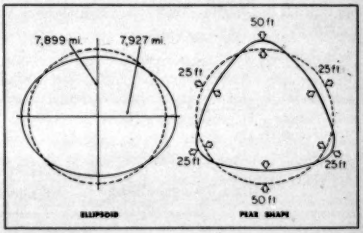

FIG. 1—Shape of the Earth from Vanguard satellite data; the drawing on the left represents the old conception of the spheroidal Earth, with a 26-mile difference between the diameters at the pole and the equator; the figure on the right shows, in exaggerated form, the effect of adding a pear-shaped component to the ellipsoid, as required to fit the Vanguard data; in each drawing the dashed circle represents an equivalent spherical Earth with equal volume (from Jastrow, R., *Missiles and Rockets*, July 20, 1959)

Any deviation of the geoid from the theoretical shape is an indication of stress in the interior of the Earth. The stresses computed from the observed shape of the geoid are greater than were commonly believed to exist. They indicate a considerable mechanical strength of the Earth, or, possibly, the presence of convection currents in the Earth's interior.

Regarding meteorology, the first meteorological satellite, Tiros, is now in orbit and performing most satisfactorily. The trajectory is nearly circular, at about 50° to the equator and at an altitude of about 700 km. The satellite is spin-stabilized in space, and is equipped with small rockets, by means of which it will be possible to keep its spin rate nearly constant at about 12 rpm. It carries two television cameras, one with a field of view of about 1300 km and a

resolution of 2.5 km, and the other with a field of view perhaps 10 times smaller in linear dimensions and a correspondingly finer resolution. Remarkable pictures have been obtained with this device. From a close study of such pictures it will be possible to discover patterns of circulation in the atmosphere, to detect incipient storms, etc. Much will be learned also by correlating the high altitude observations with meteorological observations on the ground.

The rest of this paper concerns item (1), that is, direct observations of the environment of space vehicles.

It has been known for some time that interplanetary space is filled with an extremely dilute gas that is for the most part, presumably hydrogen. It also contains particles with energies much greater than the kinetic energy corresponding to either the thermal agitation or the bulk motion of the individual particles of the interplanetary gas. These particles will be referred to hereafter by the generic name of energetic particles. They include cosmic-ray particles originating outside of the solar system, and having an energy spectrum extending to at least 10^{19} or 10^{20} ev. They include, also, particles originating from the Sun whose flux and whose energy spectrum vary with time and are correlated with the solar activity. Ordinarily, only a very small fraction of the solar particles have energies greater than several hundred Mev.

Presumably, in the inner part of the solar system and at sufficiently large distances from the planets, the conditions of interplanetary space are dominated by the Sun.

Ultra-violet rays from the Sun ionize the interplanetary gas. Because of its low density and consequent slow rate of recombination, this gas must be practically 100% ionized. It thus must form an almost perfect 'plasma,' whose behavior is determined by the long-range electric and magnetic interactions rather than by the short-range forces that appear during the collisions between gas particles.

Gravitational attraction by the Sun determines the trajectories of meteorites and micrometeorites. It also must play an important role in the distribution of density of interplanetary gas, at least in the inner part of the solar system. Another factor to be taken into account is solar radiation pressure. In fact, it has been shown that even the trajectories of artificial satellites are influenced appreciably by it. (see Figure 2)

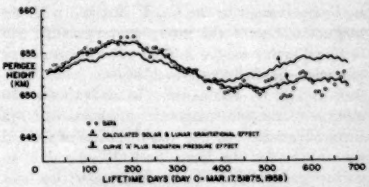

FIG. 2—Effect of solar radiation pressure on the trajectory of Vanguard I (from Musen, P., R. Bryan and A. Bailie, *Science*, 131, 935, 1960)

Presumably, the solar gravitational attraction not only tends to prevent the escape of interplanetary gas into interstellar space, but it also produces an infall of gas from interstellar space toward the Sun. Thus, part of the matter in interplanetary space may be of extra-solar origin. Most of it, however, probably originates from the Sun, being ejected in spurts on the occasion of solar eruptions and, perhaps, also continuously through some sort of evaporation processes.

The Sun has both a dipole magnetic field, as well as local and much stronger magnetic fields related mainly to sunspots. Ionized plasma flowing out of the Sun distorts and stretches the magnetic lines of force, thus carrying and spreading the magnetic field of the Sun throughout the solar system.

As we approach the Earth, we pass gradually from a region of space where the Sun is the dominant agency into a region of space where conditions are controlled primarily by our planet, while the Sun, of course, still exerts an influence.

The terrestrial effect that is felt at the largest distance is the magnetic field. In the vicinity of the Earth's surface, the Earth's magnetic field resembles that of a dipole. The magnetic field lines that cross the Earth's surface near the equator do not go very far, and they return to the Earth practically undisturbed by whatever conditions prevail in interplanetary space. As we consider magnetic field lines that cross the Earth's surface at increasingly higher latitudes, we find that they reach farther and farther into space where the strength of the Earth's dipole

field is no longer large compared with that of the general interplanetary field. They are thus more and more distorted, until eventually they no longer return to the Earth, but join with the magnetic lines of the interplanetary field.

The Earth's magnetic field affects cosmic-ray particles, producing the well-known latitude effect and E-W asymmetry. It also affects the motion of the interplanetary plasma and is, in turn, affected by it. For, when a mass of ionized gas approaches the Earth, it will be brought to a stop gradually while it compresses the lines of force (and this will happen irrespective of whether or not the plasma is originally magnetized). Notice that the effect of the gravitational attraction of the Earth on the motion of the plasma is small compared with that of the magnetic field.

As we come closer to the Earth, terrestrial gravitational attraction becomes the dominant factor. It prevents the escape of gases filtering through the Earth's crust and of those originating from inorganic chemical reactions or from the metabolism of living organisms. These gases, together perhaps with some residue of the original terrestrial atmosphere, form the present atmosphere of the Earth.

The upper layers of the atmosphere are strongly ionized by ultraviolet and X rays from the Sun, and occasionally by energetic particles of solar origin. They form the ionosphere.

The ionosphere stops rather abruptly below approximately 80 km, because atmospheric absorption prevents the ionizing radiation from penetrating to lower altitudes. Thus the Earth's surface is separated from the ionosphere and from the interplanetary plasma beyond by an electrically insulating blanket of air.

Some of the experimental investigations will be discussed in the framework of this broad picture.

One of the interesting results of these studies has been the discovery of a variability in the air drag on artificial satellites, showing corresponding changes in the air density at a given altitude. This fact was first noticed by Jacchia of the Smithsonian Institution by studying the orbit of Sputnik II. The more accurate tracking data on Vanguard I, which became available some time later, and the orbital observations on Sputnik III confirmed these results and showed that the drag fluctuates with a period close to the 27-day period of the solar rotation. This led Jacchia to correlate the changes of air density in the upper layers of the atmosphere with the periodic changes of solar activity brought about by the Sun's rotation. Presumably, when an active region appears on the visible portion of the solar disk, there is an increase in the flux of solar radiation responsible for the heating of the upper layers of the atmosphere. The consequent increase of temperature causes an outward expansion of the atmosphere and an appreciable increase of the air density at the apogee of the satellite. Jacchia's conclusions were considerably strengthened by the work of Priester, in Germany, who found that there was a close correlation between the variation of the drag on the satellite and the variation in the 20-cm radio waves emitted by the Sun. This radiation is an excellent indicator of solar activity. Shortly thereafter, Jacchia found a similar correlation between the drag and the solar radio emission at 10 cm.

In the course of his work, Jacchia made another interesting observation. He noticed that on two instances an abrupt increase in the drag on Sputnik III occurred about a day after the appearance of a large solar flare. It is possible that, in these cases, the effect was produced by the arrival of solar corpuscular streams.

Turning next to the ionosphere, rocket work by American scientists has contributed a large share of the information now available on the electron density and on the relative abundance of the various positive ions up to about 200 km. American satellites have not yet carried electron or ion probes. Russian satellites have carried such probes, and some of the results have been made available. Moreover, American as well as Russian scientists have obtained significant data on the density of ions above the ionospheric maximum by observing the refraction of the waves from the radio transmitters carried by the Russian satellites. Figure 3 summarizes some of the results.

The most impressive scientific result obtained to this date from experiments in space is the discovery of the radiation belt.

When space exploration began, the theoretical background of this discovery had been available for some time. The following facts were known: (a) In the absence of disturbing effects, charged particles can be trapped indefinitely in certain

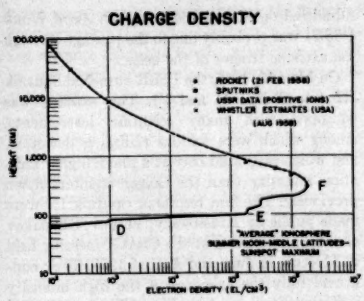

FIG. 3—Electron density in the ionosphere as a function of height (from J. E. Jackson, CSAGI Meeting, Moscow 1958)

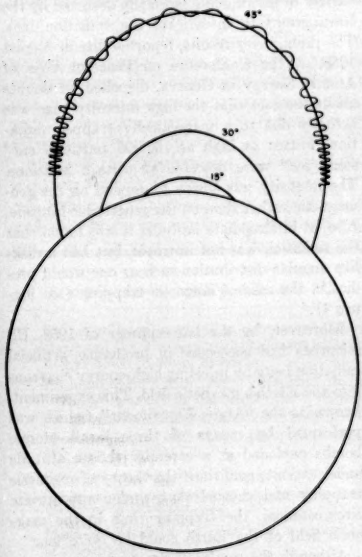

FIG. 4—An Illustrative sketch, not to scale, of the spiral path of a trapped charged particle, the guiding center of whose motion lies along the line of magnetic force that intersects the Earth's surface at a geomagnetic latitude of 45°; also shown are lines of force that intersect the Earth's surface at geomagnetic latitudes 30° and 15°, respectively (from Van Allen, J., C. McIlwain, and G. Ludwig, *J. Geophys. Res.*, 64, 271, 1959)

regions of space around a magnetic dipole (Störmer). (b) When the radius of gyration is small compared with the distance from the center of the dipole, each particle spirals about a line of force; as it moves from the weaker field found near the equator to the stronger field found near the poles, the pitch angle increases until it reaches the value of 90°, at which point, the motion is reversed and thus the particle oscillates back and forth between two symmetrically located "mirror points" (Alfvén, see Figure 4). (c) Because of the curvature of the lines of force and the radial gradient of the field strength, the trajectory of the particle undergoes a slow drift in azimuth, positive and negative particles drifting in opposite directions (Alfvén). There results an electric current, which, in the case of the dipole field of the Earth, would circle our planet from east to west.

Early in 1957 Fred Singer published an article which, for the first time, called attention to the likelihood that there may actually exist in the dipole field of the Earth a trapped radiation, consisting of charged particles which oscillate back and forth along the lines of force while drifting in longitude. Singer had advanced this hypothesis in order to explain the so-called "ring current" which is held responsible for the main phase of the magnetic storms.* Singer suggested that the particles were of solar origin and that they were allowed to enter the normally inaccessible regions of the dipole field because of perturbations in the Earth's magnetic field; he also suggested that the trapped particles, leaking along the lines of force into the lower atmosphere, would contribute to aurorae, airglow and ionospheric ionization.

The first satellites carrying detectors of energetic particles were Sputnik II (launched on November 3, 1957), Explorer I (launched on February 1, 1958), and Explorer III (launched on March 16, 1958; see Tables I and II). For each of the three satellites the detector was a single Geiger counter. Van Allen, whose group had been responsible for the instrumentation of the American satellites, reported his preliminary

* Actually it turns out that consideration of the drift alone leads to an incorrect result concerning the magnetic effects of trapped particles. Trapped particles behave like a diamagnetic gas and the drift current merely cancels one of the terms arising from the diamagnetic polarization.

results at a joint meeting of the National Academy of Sciences and the American Physical Society, held in Washington on May 1, 1958. He stated that the counting rate of the Geiger counter installed aboard Explorer I was dependent both on latitude and altitude, that it increased with altitude in a more or less regular fashion between 600 and 1000 km, but that, however, no counts were received during several minutes of radio contact, while the satellite was above 2000 km. Van Allen interpreted the lack of signal as due to a jamming of the Geiger tube by a radiation of exceptionally high intensity. He figured that the 'true' counting rate (such as would have been recorded with zero dead time) must have been greater than 35000 sec^{-1} (as compared with a counting rate of about 20 sec^{-1} recorded below 600 km). The data obtained with Explorer III were in agreement with those of Explorer I. They were more complete, however, because Explorer III, unlike Explorer I, had a device capable of recording the counting rates continuously and sending back the information on command from the Earth, when the satellite was in radio contact with a receiving station.

On the basis of these results, Van Allen concluded that a zone of very high intensity radiation exists around the Earth. He called attention to the fact that the radiation is detected through a wall thickness of 1.5 g cm^{-2}, and yet does not penetrate to a depth of 600 km. Since the residual atmospheric thickness above 600 km is negligible, Van Allen concluded that the radiation must consist of charged particles that are restrained from reaching the vicinity of the Earth by the Earth's magnetic field. He suggested that these particles are of solar origin, that they penetrate the forbidden region of the Earth's magnetic field through some sort of perturbation of the field, and that subsequently they remain trapped in this region.

Despite Singer's prediction, the discovery of a more or less permanent trapped radiation of the very great intensity revealed by Van Allen's observations, came as a major surprise.

Sputnik II, because of its comparatively low apogee (see Table II) had not penetrated deeply into the radiation belt. However, the small increase in counting rate, detected by Sputnik II at latitudes above 60° (and reported by Vernov, Grigorov, Logachev and Chudakov in a paper submitted on May 4, 1958 to *Dok. Akad. Nauk USSR*) was probably due to the passage through the extreme fringes of the belt.

On May 15, 1958, the USSR launched Sputnik III (see Tables II and V). This satellite was equipped with many scientific instruments, among which were various radiation detectors, and which saturated only at a much higher radiation intensity than the Geiger counters flown previously. The first results of Sputnik III were made public by Krassowsky, Vernov, Chudakov and their associates at the CSAGI meeting held in Moscow in July and August 1958. They confirmed fully the existence of the high intensity radiation discovered by Van Allen.

On August 7, 1958 (see Tables I and VI), the USA launched Explorer IV equipped with a variety of instruments especially designed by the Iowa group to investigate the radiation belt. The preliminary results, reported late in August 1958, at the Conference on Peaceful Uses of Atomic Energy in Geneva, dispelled all doubts about the fact that the high intensity zone was actually due to a magnetically trapped radiation. Fluxes as high as 100,000 particles cm^{-2} $ster^{-1}$ sec^{-1} were detected at certain locations. The intensity was shown to depend on the geomagnetic rather than on the geographic latitude. Also, at intermediate latitudes it was found that the radiation was not isotropic, but had a disk-like angular distribution such as one would predict in the case of magnetic trapping (see Figure 4).

Moreover, by the late summer of 1958, US scientists had succeeded in producing artificial radiation belts by injecting high-energy electrons into the Earth's magnetic field. This experiment, known as the "Argus Experiment" (which was performed by means of three small atomic bombs exploded at a carefully chosen altitude and location), confirmed the theory of magnetic trapping and showed that, under appropriate circumstances, the trapping time in the magnetic field of the Earth could be quite long.

Although the results of the Argus experiment were not made public until the spring of 1959, in the fall of 1958 the existence of a trapped radiation belt was regarded generally as an established fact. However, many questions concerning its nature, its spatial distribution, and its origin still remained unanswered. For example—and this was most important—it was

not experimentally known whether the radiation intensity went through a maximum with increasing distance from the Earth, or whether it kept on increasing asymptotically toward some limiting value.

Some of these questions have now been answered, and I would like to summarize here the most significant results obtained during the last one and one-half years.

As a working hypothesis, it was assumed from the outset that the trapped radiation consisted mainly of electrons and protons. Sputnik III and Explorer IV carried a number of different detectors, and each of them had a different response to electrons and protons of various energies (see Tables V and VI). It immediately became apparent that the ratios of the counting rates of the various detectors varied greatly from point to point within the radiation belt. In other words, the measured fluxes were strongly dependent, both in absolute and in relative values, on the measuring instrument. It was concluded correctly that the composition and the energy spectrum of the radiation were different at different locations.

Many of the American and Russian vehicles, including Sputnik II, Explorer I, Explorer III, and Explorer IV, carried Geiger counters, with wall thicknesses ranging from a few tenths of one g cm^{-2} to slightly more than one g cm^{-2} (including the vehicle skin). These counters detect, with practically 100% efficiency, electrons of a few Mev energy, and protons of a few tens of Mev energy, which can penetrate the wall. They also detect, with much lower efficiency, electrons down to a few tens of kev energy, through the intermediary of the X rays which they produce in the counter walls.

TABLE V—*Instrumentation of Sputnik III*

1. NaI scintillator, used (a) as a counter (35 kev bias); and (b) with a current integrator (detects X-rays down to about 20 kev).
2. Photomultiplier with thin phosphor, under 4×10^{-4} g cm^{-2} Al foil, used with a current integrator (detects electrons, E > 10 kev).
3. Photomultiplier with thin phosphor, under 8×10^{-4} g cm^{-2} Al foil.
4. Cerenkov counter (detects heavy c.r. primaries).
5. Spherical ion trap (measures ion densities from 10^4 to 25×10^4 ions/cm^3).
6. Mass spectrometer to determine composition of ionosphere.
7. Magnetometer.
8. Manometers for pressures from 10^{-9} to 10^{-5} mm Hg.
9. Micrometeorite detectors.
10. Field-mill electrometer.
11. Radio transmitters to detect radio "rise" and radio "sets."

TABLE VI—*Instrumentation of Explorer IV*

A. Plastic scintillator; shielding: 0.4 g cm^{-2} Al; counts:
   Electrons, E > 650 kev
   Protons, E > 10 Mev
   X-rays, E $\gtrsim$ 400 kev (low efficiency)

B. CsI scintillator; 0.92 g cm^{-3} thick; shielding: 1 mg cm^{-2}; measures total energy loss of:
   Electrons, E > 20 kev
   Protons, E > 400 kev
   X-rays, (high efficiency)

C. G.M. Counter, 1.2 g cm^{-2} wall; unshielded; counts:
   Electrons, E > 3 Mev
   Protons, E > 30 Mev
   X-rays, E $\gtrsim$ 40 kev (low efficiency)

D. G.M. Counter, 1.2 g cm^{-2} wall; 1.6 g cm^{-2} Pb shield; counts:
   Electrons, E > 5 Mev
   Protons, E > 40 Mev
   X-rays, E $\gtrsim$ 80 kev (low efficiency)

Late in 1958 and early in 1959, the USA and the USSR launched a number of deep-space probes (see Tables III and IV). Some of them, namely Pioneer III and Mechta (see Figure 5), and Pioneer IV (see Figures 6 and 7), carried Geiger counters similar to those carried by the satellites. The two most important facts brought to light by these probes were: (1) The high-intensity radiation is confined to a belt around the Earth; at great distances, only the normal cosmic-ray flux is detected. (2) As one moves farther and farther away from the Earth, the counting rate of the Geiger counter goes through two separate maxima; thus there is an 'inner zone' and an 'outer zone,' separated by a slot. (See Figures 8, 9, and 10.)

These results were announced first by Van Allen, and then confirmed by the Russian workers. The decrease of the intensity level beyond the maximum was also detected by STL and Iowa physicists by means of an ionization chamber installed aboard Pioneer I.

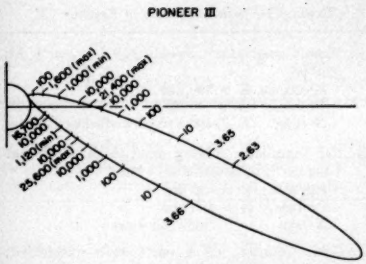

FIG. 5—A geographical plot, to scale, of the projection on a (rotating) meridian plane of the trajectory of Pioneer III; the semicircle at the left represents the cross section of the solid Earth; polar coordinates are radial distance from the center of the Earth and the geographical latitude; the vertical axis is the geographical axis of the Earth with the north end up; the numbers are true counting rates at selected positions along the trajectory; the outbound leg of the trajectory is the upper portion of the curved line (from Van Allen, J. and J. Frank, *Nature*, 183, 430, 1959)

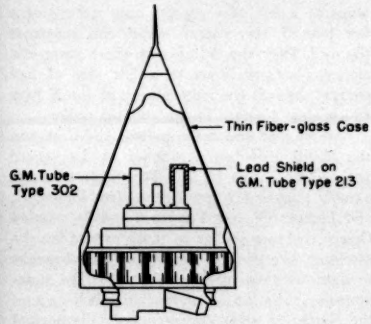

FIG. 6—Physical arrangement of radiation detectors in conical payload of Pioneer IV; base diameter 23 cm; total payload weight 6.1 kgm; the arrangement of Pioneer III was identical except for omission of the shield over the 213 tube (from Van Allen, J. and L. Frank, *Nature*, 184, 219, 1959)

Comparing the data of Pioneer III, Mechta, and Pioneer IV, Van Allen established another important fact. Although the population of the inner zone is comparatively stable, that of the outer zone shows large scale fluctuations, which are presumably connected with solar activity. Figure 11 illustrates dramatically this effect. Note that the flight of Pioneer IV occurred a few days after a period of enhanced solar activity and magnetic storms.

In the meantime, more specific information on the composition of the trapped radiation was becoming available, through both a detailed comparison of the counting rates of the various instruments installed on Explorer IV and Sputnik III, and direct observations by means of

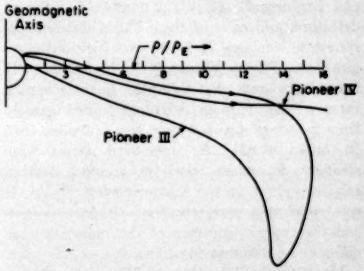

FIG. 7—Plots of the projection of the trajectories of Pioneer III and Pioneer IV on a geomagnetic plane (centered dipole model); unit of distance, ρ_E = 6,371 km. (from Van Allen, J. and L. Frank, *Nature*, 184, 219, 1959)

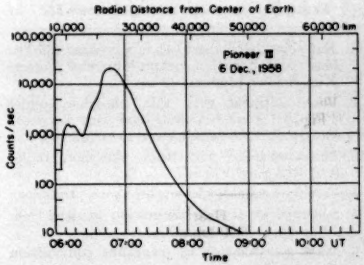

FIG. 8—Semi-log plot of true counting rate of the 302 Geiger-Muller tube versus time of observation on the outbound leg of the flight of Pioneer III; radial distance from the center of the Earth is shown at the top of the figure; the geographical longitude during the period shown was 30°W. at 0600, 0° at 0630, 5°E. at 0700, 4.6°E. at 0730, 2°E. at 0800, 2°W. at 0830 (from Van Allen, J. and L. Frank, *Nature*, 183, 430, 1959)

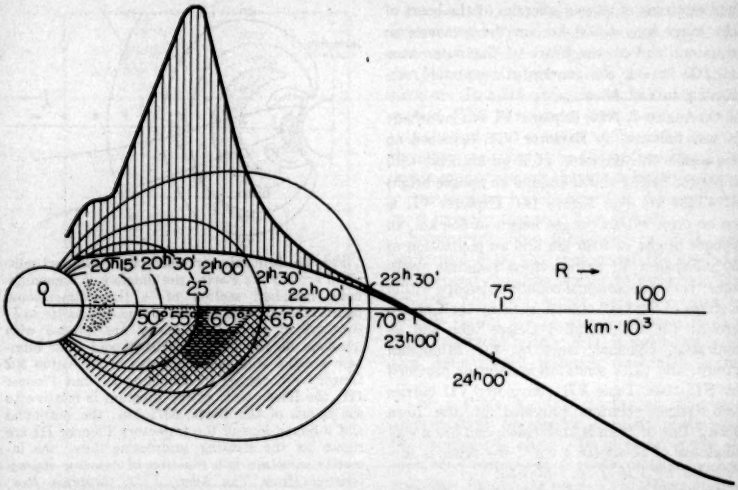

FIG. 9—The trajectory of the rocket in geomagnetic coordinates; Moscow time and the intensity (vertical lines drawn from the trajectory) are shown along the trajectory; the total ionization is used as a measure of the intensity; the magnetic force lines intersecting the surface of the Earth at latitudes of 50°, 55°, 60°, 65°, and 70° are shown; the magnetic field is taken to be that of a dipole whose geomagnetic pole coordinates are 78.5°N and 69°W; the inner zone is indicated by the dotted region, the outer zone by the shaded region; the density of shading gives a qualitative picture of the intensity distribution in the second zone (from Vernov, S., A. Chudakov, P. Vakulov, and Yu. Logachev, *Soviet Physics Doklady*, **4**, 338, 1959)

photographic plates and magnetic spectrometers flown with rockets into the lower edge of the radiation belt. Figure 12 shows the proton spectrum between 75 and 400 Mev at the fringe of the inner zone (about 1000 km near the equator). Figure 13 shows the spectrum of electrons between 80 and 500 kev measured between 600 and 1000 km at high latitude, where the outer belt reaches down to fairly low altitudes. No protons with more than 1 Mev energy were found in this region. Table VII gives some tentative estimates of the intensities of protons

TABLE VII—*Van Allen's Estimates of Particle Flux*
(from *J. Geophys. Res.*, **64**, 1683, 1959)

Heart of inner zone (3600 km on geom. equator)	Heart of outer zone (16,000 km on geom. equator)
(a) Electrons, $E > 20$ kev: max. unidir. intens: $\sim 2 \times 10^9$ cm^{-2} sec^{-1} ster^{-1}	(a) Electrons, $E > 20$ kev: omnidir. intens: $\sim 1 \times 10^{11}$ cm^{-2} sec^{-1}
(b) Electrons, $E > 600$ kev: max. unidir. intens: $\sim 1 \times 10^7$ cm^{-2} sec^{-1} ster^{-1}	(b) Electrons, $E > 200$ kev: omnidir. intens: $\sim 1 \times 10^8$ cm^{-2} sec^{-1}
(c) Protons, $E > 40$ Mev: max. omnidir. intens: $\sim 2 \times 10^4$ cm^{-2} sec^{-1}	(c) Protons, $E > 60$ Mev: omnidir. intens: $\lesssim 10^3$ cm^{-2} sec^{-1}
	(d) Protons, $E < 30$ Mev: no information

and electrons of various energies at the heart of the inner zone (3000 km on the geomagnetic equator) and at the heart of the outer zone (16,000 km on the geomagnetic equator), according to Van Allen.

On August 7, 1959, Explorer VI was launched; it was followed by Explorer VII, launched on September 19. Explorer VI is on an orbit with a perigee height of 252 km and an apogee height of 42,434 km (see Figure 14). Explorer VII is on an orbit with a perigee height of 556 km, an apogee height of 1086 km and an inclination of 50°. Explorer VI carries three radiation packages: (1) a proportional counter telescope within a shield of 5 g cm^{-2} of lead, built by the Chicago group; (2) a thin-walled Geiger tube and an ionization chamber built by the Minnesota group; and (3) a scintillation detector provided by STL (see Table VII). Explorer VII carries two Geiger counters provided by the Iowa group. One of them is unshielded, and has a wall thickness of about 0.5 g cm^{-2}; the other is surrounded by 1.15 g cm^{-2} of lead.

A wealth of new information has come from

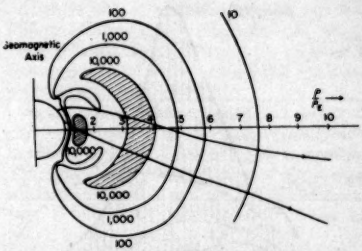

FIG. 10—Intensity structure of the trapped radiation around the Earth; the diagram is a geomagnetic meridian section of a three-dimensional figure of revolution around the geomagnetic axis; contours of constant intensity are labeled with numbers 10, 100, 1000, and 10,000, and these numbers are the true counting rates of an Anton 302 Geiger tube carried by Explorer IV and Pioneer III; the linear scale of the diagram is relative to the radius of the Earth, 6371 km; the outbound and inbound legs of the trajectory Pioneer III are shown by the slanting, undulating lines; the intensity structure is a function of detector characteristics (from Van Allen, J., *J. Geophys. Res.*, 64, 1683, 1959)

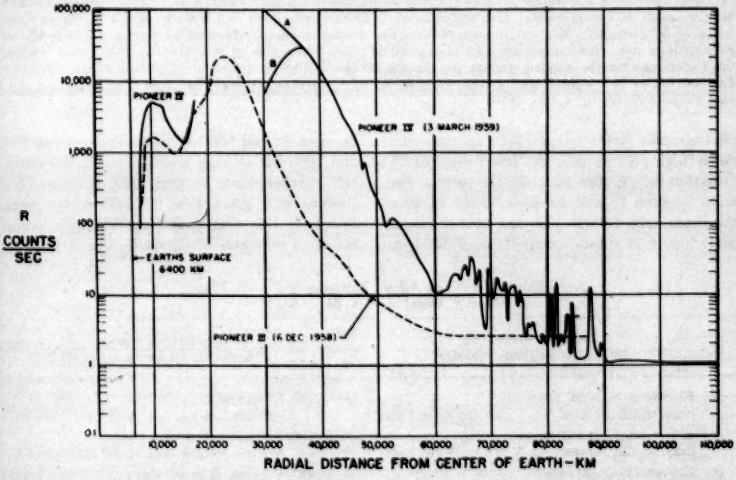

FIG. 11—A comparative plot of the radiation intensities as measured with nearly identical Anton 302 Geiger tubes in Pioneer III and Pioneer IV; the trajectories were not identical, the most important difference being that Pioneer IV cut through the inner zone several degrees closer to the equator, at a radial distance of about 10,000 km. (from Van Allen, J., *J. Geophys. Res.*, 64, 1683, 1959)

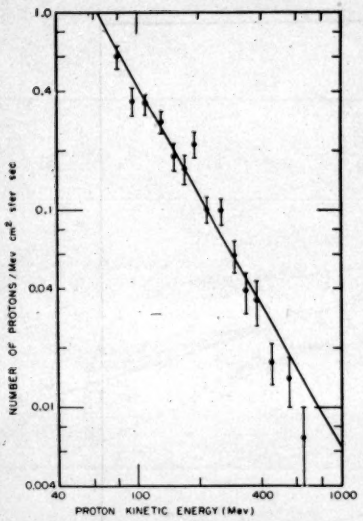

FIG. 12—The absolute energy spectrum of protons above 75 Mev in the Lower Van Allen radiation belt at an altitude of 1200 km; the line is at least-squares fit of the equation $N = N_1T^{-n}$ to the data and gives $N_1 = (2.1_{-0.7}{}^{+1.0}) \times 10^5$ protons Mev^{-1} $sterad^{-1}$ sec^{-1} cm^{-2} and $n = 1.84 \pm 0.08$ (from Freden, S. and R. White, *Phys. Rev. Letters*, 3, 9, 1959)

the analysis of the data obtained with these satellites.

Figure 15 shows the threefold coincidence rate of Simpson's telescope on Explorer VI and the single counting rate of the middle counter for a given passage of the satellite plotted against altitude above the Earth's surface. Threefold coincidences are produced only by comparatively energetic particles, that is, protons with more than 75 Mev or electrons with more than 13 Mev kinetic energy whereas single pulses can be produced also by fairly low-energy electrons (down to about 300 kev) through the intermediary of X rays. It is evident that high-energy particles are present only in the inner belt, and that the counts recorded by the single counter in the outer belt are due entirely to low-energy electrons.

Figures 16 and 17 represent some additional results obtained from single counting rates of the counters carried by Explorer VI. They show that the outer electron belt has a complex structure. In many passages two separate peaks appear. The Minnesota instruments indicate that the radiation is softer at the outer than at the inner peak. Both the Chicago and the Minnesota groups remark that the intensity maxima in the electron belt observed at different latitudes lie along magnetic lines of force.

Before continuing this summary of the experimental data, the problem of the origin of the trapped radiation should be discussed. The problem arises, of course, because a charged particle should not be able to enter a captive orbit any more readily than it can leave it, so that some special injection mechanism is required.

One possible injection mechanism, suggested independently by several scientists, is the neutron cosmic-ray albedo. Upon entering the atmosphere, cosmic-ray particles undergo nuclear collisions. Among the products of these collisions

TABLE VIII—*Instrumentation of Explorer VI*

A. Counter telescope, 5 g cm^{-2} Pb shielding (Chicago).
Coincidence rate measures N° of:
Electrons, E > 13 Mev
Protons, E > 75 Mev
Single rate measures N° of:
Electrons, E > 13 Mev
Protons, E > 75 Mev
X-rays, E $\gtrsim$ 300 kev (low efficiency)

B. G.M. Counter, unshielded, wall 0.02″ steel (Minnesota); counts:
Electrons, E > 2 Mev
Protons, E > 16 Mev
X-rays, E $\gtrsim$ 30 kev (low efficiency)

C. Ionization chamber, unshielded, wall 0.02″ Al (Minnesota).
Detects: Approximately same radiation as B.

D. Plastic scintillator, under 3 mg cm^{-2} Al (S.T.L.); counts:
Electrons, E > 200 kev
Protons, E > 2 Mev
X-rays, E > 100 kev (low efficiency)

E. Search coil magnetometer (S.T.L.).

F. Micrometeorite detectors, TV camera to scan clouds, radio propagation exper.

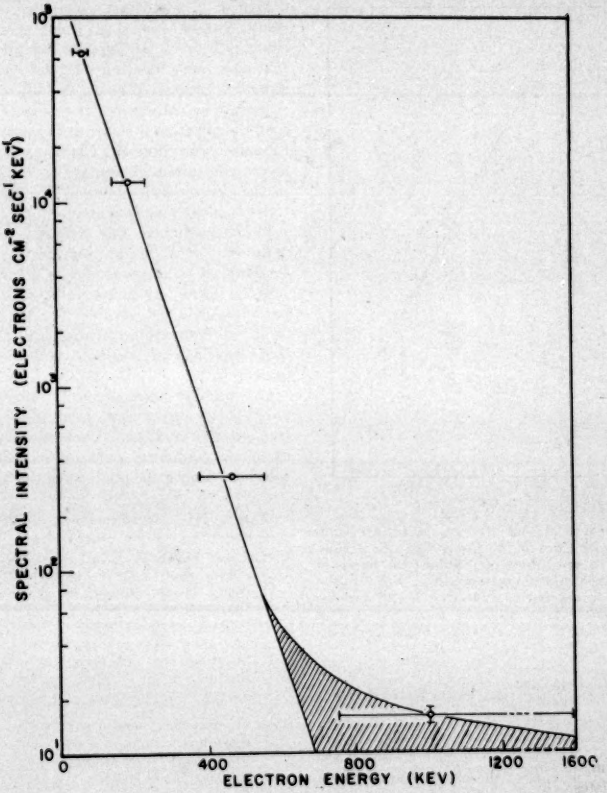

FIG. 13—Electron spectrum measured at high latitude, between 600 and 1000 km altitude (from Walt, M., L. Chase, J. Slaids, W. Imhof, and J. Knecht, COSPAR Meeting, Nice, January 1960)

are a number of neutrons that are projected upward, and travel, undeflected, through the magnetic field. On the way out, some of the neutrons decay into electrons and protons, injecting these charged particles into trapped orbits. Data on the neutron albedo spectrum are now available; it is thus possible to compute the source spectrum of electrons and protons. Making suitable estimates of the mean lives of these particles in the trapped orbits, it is possible to compute the particle density and spectrum in the radiation belt. Computations of this kind were made first by Singer and refined later by others. An interesting point emphasized by Dessler is the effect of the so-called 'Cape Town anomaly.' In the general area of Cape Town, the Earth's magnetic field is abnormally low. This should bring the mirror points located on the lines of force that pass through this region into the lower atmosphere. Atmospheric scattering and absorp-

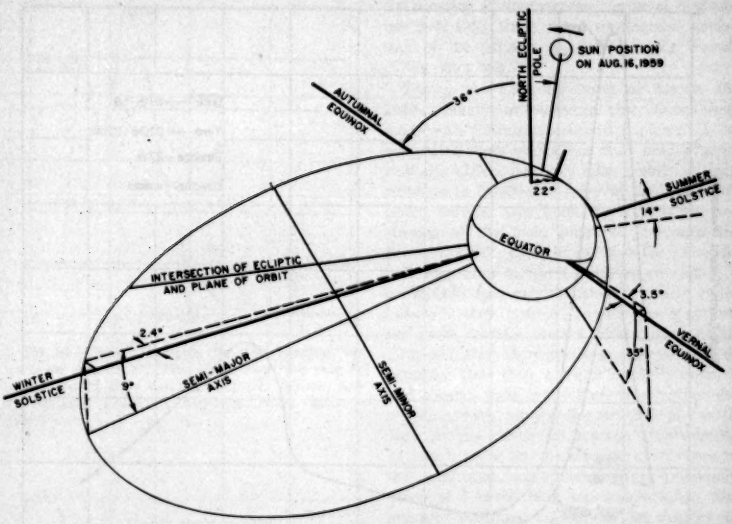

FIG. 14—The orbit of Explorer VI in space; the angle between the plane of the orbit and the Earth's equatorial plane is 47°; the orbital plane is tipped 38° to the plane of the ecliptic; on August 16 during the geomagnetic storm the major axis was directed about 125° away from the Sun (from Arnoldy, R., R. Hoffman, and J. Winckler, *J. Geophys. Res.*, in press)

tion would then decrease the population along these lines of force, and the drift in longitude would spread the depletion to a shell around the Earth.

The computed proton spectrum has been found to be in reasonable agreement with that observed in the inner zone by means of photographic plates. This fact, together with the relative stability of the inner zone, lends considerable support to the assumption that the high-energy particles, found primarily in the inner zone, originate indeed from the decay of neutrons.

It seems very difficult, however, to assume that most of the low-energy electrons, found predominantly in the outer zone, have a similar origin. As pointed out by Gold, this hypothesis is completely ruled out on the ground of energy balance if it is true—as it seems very likely—that aurorae are due to a discharge of the radiation belt along the lines of force into the polar regions of the upper atmosphere, because the energy supplied by the neutron albedo falls short, by several orders of magnitude, of the average energy dissipated in the auroral displays.

Another possible mechanism considered by various scientists is the injection of particles of solar origin, which I already mentioned. This requires some sort of disturbance of the Earth's magnetic field, brought about, presumably, by the same plasma cloud that also carries the particles. No detailed theory of this phenomenon exists, but various interesting points have been brought out. For example, Gold has emphasized the importance of the non-ionized atmospheric layer that insulates the earth from the highly conducting gases in the exosphere and in interplanetary space. This makes it possible for the charged particles that, at some time, are contained within a tube of force to be transferred to another tube of force without

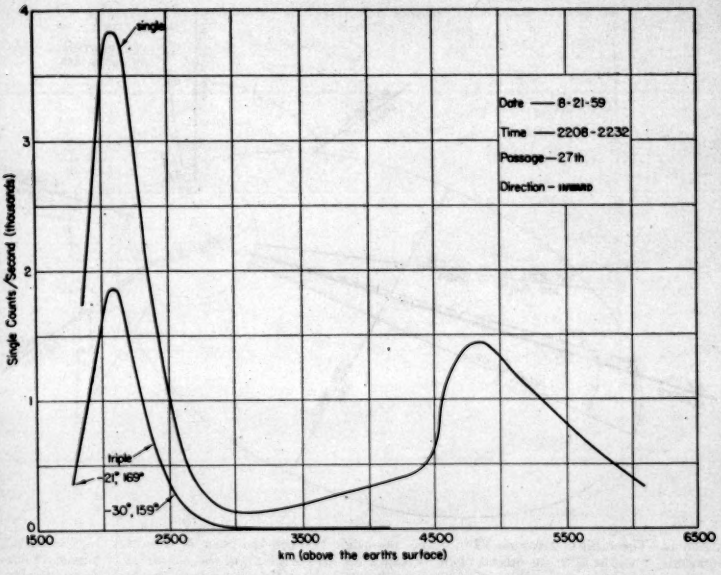

FIG. 15—The counting rate as a function of altitude near perigee for the single counter channel and for the triple coincidence channel; the peak at the left is due to protons from the inner Van Allen region having energies greater than 75 Mev; the bremsstrahlung from electrons produces the peak on the right; note that the detection of energetic particles from the triple coincidence counter is limited to cosmic radiation beyond the altitude of 3,500 kilometers (from Fan, C., P. Meyer, and J. Simpson, COSPAR Meeting, Nice, January 1960)

any expenditure of energy. Such a transfer of particles might help to explain both the injection of particles and their spread throughout the radiation belt.

Of course, one should also bear in mind that what needs to be injected is *energy* rather than *particles*. Electrons are certainly produced within the radiation belt by ionization of neutral atoms coming from the atmosphere below. These electrons have much lower energies than those detected in the radiation belt, but it is conceivable that they may become accelerated by hydromagnetic disturbances induced by the arrival of a plasma cloud. One might ask, however, whether or not it is reasonable to assume that the plasma cloud should inject its energy into the Earth's magnetic field without injecting, at the same time, the particles of which it is formed.

The problem of the origin of the outer belt is still unsolved. However, certain correlations between intensity variations in the outer belt and solar or geophysical effects offer suggestive clues. I have already noted that in March 1959 Pioneer IV detected an increase in the population of the outer belt following solar disturbances. This, of course, is evidence of a solar origin either for the particles found in the belt or at least for their energy. Since that time, further analysis of the data of Explorer IV and new observations by Explorer VI and Explorer VII have provided additional information.

Rothwell and McIlwain, of the Iowa group, relating results of Explorer IV, reported that on

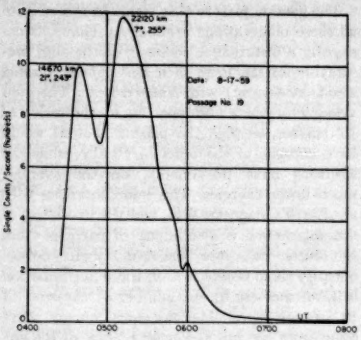

FIG. 16—Passage through the two electron regions on August 17, 1959; single counting rate as a function of time (from Fan, C., P. Meyer, and J. Simpson, COSPAR Meeting, Nice, January 1960)

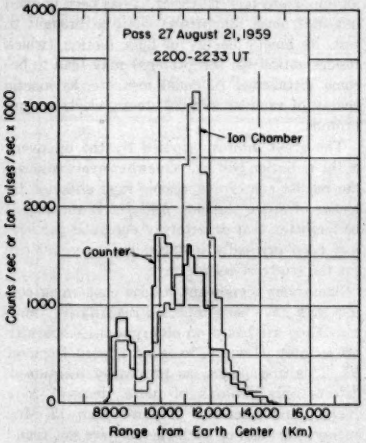

FIG. 17—Radiation levels on the oncoming portion of Pass 27, which shows three distinct radiation regions; the Van Allen inner zone appears at 8500 km; the outer zone at 11,500 km and the new intermediate zone close to 10,000 km (from Arnoldy, R., R. Hoffman, and J. Winckler, *J. Geophys. Res.*, in press)

the occasion of the magnetic storms of September 3–5, 1958, there was a considerable depletion of the particle population in the 'horns' of the outer belt.

During the magnetic storm of August 16, 1959, a number of interesting observations were made with instruments aboard Explorer VI. In comparing these results, one must bear in mind that the various detectors differ greatly in their response to particles of different kinds and different energies (see Table V). (a) At the beginning of the main phase of the magnetic storm, the STL group found that the radiation belt was more or less normal up to almost 7 earth radii (geocentric). Around 7 earth radii, however, they noticed considerable structure and some decrease. At the next passage, about 12 hours later, there was a modest increase of intensity (less than a factor of 2) between 3 and 4 earth radii, while there was further depletion and still considerable structure at 7 earth radii. At the subsequent passage, after another 12 hours, there was an increase everywhere in the outer zone, while the structure previously noted at 7 earth radii was disappearing. The intensity continued to increase for another 48 hours; then it began to decrease slowly and, after two weeks, was still above the pre-storm value. (b) The Chicago group found that, about two days after the beginning magnetic storm, the outermost maximum (as measured with the shielded counter) had increased considerably in intensity, and had moved to a smaller range. (c) The Minnesota group found that, one day after the beginning of the storm, the outer zone was considerably depleted. The radiation, dumped into the atmosphere on that occasion, was thought to be responsible for the aurora observed at the same time. There was then a gradual recovery of the particle population coincident with the recovery of the magnetic field. For several days after the storm, the particle density was well above the pre-storm value.

Finally, the Iowa group reported the following observations made during the magnetic storms of November 28, 1959 and of March 31, 1960, by means of the unshielded counter aboard Explorer VII. To quote from a communication presented at the recent meeting of the American Geophysical Union, "The effects of the storm (of 28 November, 1959) were, firstly, to greatly deplete the intensity of trapped radiation at high

latitudes beyond the peak of the outer zone. The outer zone was thus made much narrower, and it moved towards lower latitudes. Initially very intense fluxes were observed in the peak, and then these gradually disappeared so that on 29 November the counting rate of the counter was only about one-tenth that on 28 November. This effect was noted in both hemispheres. . . .

"The (outer) zone was stable on 27 November, but very disturbed on the next day, when a 3-second wide peak at 0336.30 Z was over an auroral arc. Furthermore, a monochromatic 6300 Å sub-visible arc was under the outer zone throughout the night.

"It appears that the visible auroral arc may have been generated following a very rapid dumping out of trapped particles. Then over a period of many hours more particles were scattered out and these caused the sub-visible wide red arc. . . .

"The most recent and thus far the most drastic observed modification of the outer zone occurred during the period 31 March to 10 April 1960. The time relationship to the very great magnetic storm which began on 31 March leaves very little doubt of the causal association with this event. For several weeks previous to the event the outer zone had been relatively stable in intensity and position. The intensity as observed with the lightly shielded tube was about 200 counts per second. On 31 March–1 April the outer zone as observed at 1000 to 1100 km altitude almost completely disappeared (less than 10 counts per second). Wide-spread aurorae at low latitudes were reported, favoring the view that the trapped radiation was being precipitously dumped into the atmosphere by magnetic perturbation. The outer zone recovered rapidly in intensity (showing at times considerable detailed structure); by a week later the intensity had built up to over 10,000 counts per second. The intensity then gradually declined toward its pre-storm level."

Another point of considerable significance in connection with the origin of the outer radiation belt is that in its excursion beyond the outer fringes of the belt, Explorer VI has not, so far, encountered any flux of energetic electrons comparable with that found within the radiation belt. This seems to rule out the assumption that the electrons found in the radiation belt arrive from the Sun with their full energy.

The general picture that seems to evolve from all these observations is about as follows. Occasionally a disturbance comes from the Sun, presumably in the form of a fast-moving plasma cloud (or tongue) with a sharp front. The bulk velocity of the cloud may be of the order of 10^8 cm/sec, so that the plasma protons would have energies of the order of 10 kev, while the electrons have presumably, on the average, much lower energies. The cloud interacts with the Earth's magnetic field, and the first effect of this interaction is a dumping of particles from the outer belt into the atmosphere. Subsequently, there occurs, within the outer radiation belt, an increase in the number of electrons of 10 kev or more. The necessary energy must come from the initial kinetic energy of the gas cloud. The electrons that become accelerated may be present already in the radiation belt, or may be injected into it from the cloud. The mechanism of the energy transfer is still obscure. It certainly involves hydromagnetic disturbances, because the collision mean free path is too long for electron-proton collisions to play an important role. However, it has been pointed out that, once the plasma cloud is brought to rest, its kinetic energy of bulk motion (which resides entirely in the protons) may tend to become distributed in equal measure, as kinetic energy of random motion, among electrons and protons.

The great interest aroused by the discovery of the radiation belt has somewhat overshadowed the results concerning cosmic rays obtained by means of space vehicles. And yet it should not be forgotten that detectors of energetic particles had been originally installed on space vehicles for the study of cosmic rays.

Some very significant results concerning cosmic rays have been reported recently by Simpson. They are based on observations made with his counter telescope, installed aboard Explorer VI. This instrument, as previously mentioned, detects only protons of more than 75 Mev energy, and electrons of more than 13 Mev energy. Particles of such energies are not found in the radiation belt beyond about 5 earth radii.

Simpson's results have to do with the so-called Forbush decreases. It has been known for many years that often the cosmic-ray intensity on the Earth drops sharply by a few per cent at the beginning of a magnetic storm. This de-

crease, discovered by Forbush, is ascribed to a modulation of the cosmic-ray intensity by a changing magnetic field. Until recently, however, there was no experimental information on the extension and location of the modulating mechanism. On the occasion of the magnetic storm of August 15, 1959, Simpson observed a Forbush decrease occurring at 6 earth radii simultaneously with a similar decrease on the earth. This result shows that the modulation does not occur in the vicinity of our planet.

Magnetic field measurements are also related to the problem. Vanguard III carries a proton-precession magnetometer, whose results are currently being analyzed. They cover a range of altitudes between 500 and 3700 km. To explore the magnetic field at larger distances from the Earth, Sonnett and his collaborators at STL have installed search-coil magnetometers aboard Pioneer I and Explorer VI. The coil is fixed with respect to the spinning vehicle, and thus measures the component of the magnetic field perpendicular to the spin axis. The results of the measurements may be summarized as follows: up to about 5 earth radii from the center of the Earth, the measured magnetic field agrees with that computed from the known dipole moment of the Earth. Beyond 5 earth radii, however, systematic deviations from the theoretical dipole field begin to appear (Fig. 18). They can be accounted for quantitatively by assuming the existence of a ring current of several million amperes, centered at 9 or 10 earth radii. Between 12 and 15 earth radii, there are violent, short-time fluctuations, with periods of the order of seconds, that are ascribed to hydromagnetic disturbances. Beyond about 15 earth radii, the field becomes quiescent and settles down to a value of several gammas, which appears to be characteristic of interplanetary space.

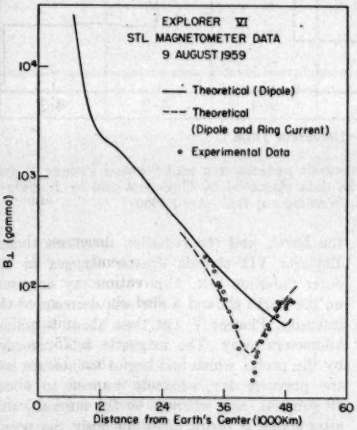

FIG. 18—Measurements of the magnetic field component perpendicular to the spin axis of Explorer VI, showing the effect of a 'ring current' (from Sonett, C., et al., Meeting of the American Geoph. Union, Washington, D.C., April 1960)

Previous measurements by Dolginov, with a magnetometer installed aboard Mechta, had shown an anomaly in the geomagnetic field indicating a ring current at 3 or 4 earth radii. This anomaly has not been found in the data of Pioneer I or Explorer VI.

Finally, some of the preliminary but very exciting results of Pioneer V (Fig. 19), are now discussed. This deep-space probe was launched on March 6, 1960 and is now (May 9, 8:00 p.m., Pacific standard time) 13,450,000 kilometers away, travelling along a line at approximately 45° to the Earth-Sun line.

Pioneer V carries several radiation detectors and a magnetometer similar to those of Ex-

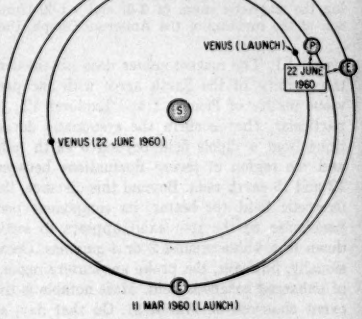

FIG. 19—Orbit of Pioneer V

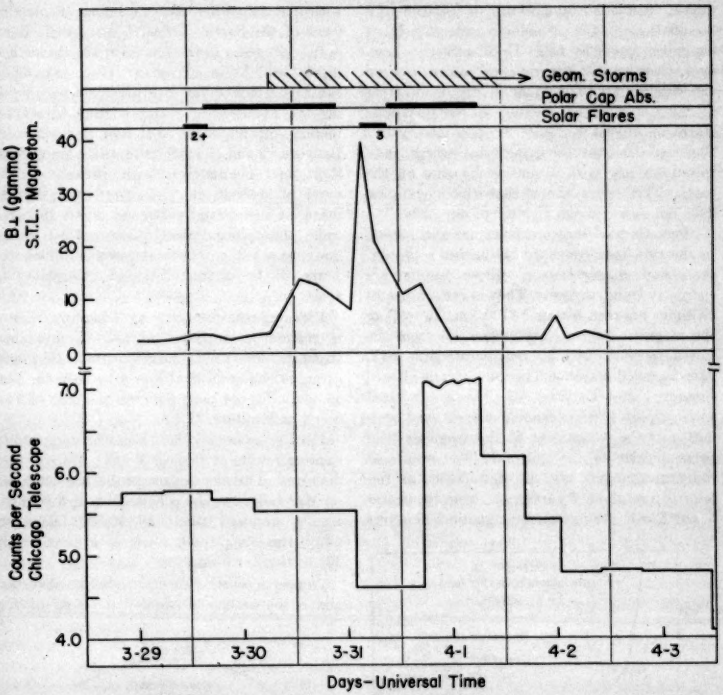

FIG. 20—Measurements of magnetic field and energetic particles flux made aboard Pioneer V during the magnetic storm of 3-31 and 4-1-60 (from the data presented by C. Sonett and by J. Simpson at the meeting of the American Geoph. Union, Washington, D.C., April 1960)

plorer VI. The magnetometer data obtained in the vicinity of the Earth agree with the previous results of Pioneer I and Explorer VI; in particular, they confirm the systematic deviations from a dipole field beyond 5 earth radii and the region of severe fluctuations between 12 and 15 earth radii. Beyond this distance, the magnetic field (or better, its component perpendicular to the spin axis) appears to settle down to a value around 2 or 4 gammas. Occasionally, however, the probe encounters regions of enhanced magnetic field. Most notable is the event observed on March 31. On that day, as noted before, a severe magnetic storm began on the Earth, and the radiation detectors aboard Explorer VII showed drastic changes in the outer radiation belt. Also, cosmic-ray detectors on the Earth showed a Forbush decrease of the intensity. Pioneer V was then about 5 million kilometers away. The magnetic field recorded by the probe, which had begun to increase late the previous day, suddenly jumped to about 40 gammas, and returned to the normal value after about 24 hours. Simultaneously, Simpson's telescope detected a Forbush-type decrease (Fig. 20). Considerable solar activity occurred at the time. The following day, while the magnetic field was recovering to its original value and al-

most simultaneously with the appearance of a solar flare, both Simpson's and Winckler's radiation detectors revealed the arrival of high-energy protons and electrons (or photons), presumably produced by the solar flare.

These observations appear to confirm the existence of 'magnetized plasma clouds' emitted by the Sun and traveling through space, to produce, upon arrival on the Earth, magnetic storms and other geophysical effects. They also confirm Simpson's previous conclusions that the mechanism responsible for the Forbush decreases is not centered at the Earth.

Energetic electrons were detected by Pioneer V also in the absence of solar flares. At no time, however, was the flux of energetic electrons in outer space comparable with that found within the trapped radiation belt. This is further indication that these electrons are accelerated locally.

Highlights of the Planetary Sciences Program

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The April meeting of the American Geophysical Union included a program of contributed papers in planetary physics arranged by the Planning Committee on Planetary Science. The program comprised 68 papers arranged in eight sessions. Many of the papers were of exceptional interest, and the total number of contributions far exceeded the expectations of the Planning Committee.

The opening session of the Planetary Sciences Program included several papers on the origin of the Van Allen belt, a problem which constitutes one of the most interesting and controversial questions in current research. Until recently it had been regarded as very probable that the energetic particles of the *inner* belt are produced by the beta decay of cosmic ray neutrons, whereas the greater part of the particles of the *outer* belt are instead injected directly from corpuscular streams emitted by the sun. The hypothesis of solar injection had been considered demonstrated by the comparison of Pioneer III and Pioneer IV data, which indicated a large increase in the intensity of the outer zone immediately following a major solar event in February 1959. However, the data returned more recently by the Explorer VI satellite indicate some puzzling features in the relation between solar events and the properties of the outer belt. For example, at the commencement of a magnetic storm the outer belt decreased, before subsequently increasing to several times its initial intensity. Furthermore, the belts have a more complex spatial structure than had been realized prior to the launching of this satellite. Stimulated in part by these results, and by new measurements of the neutron flux in the outer atmosphere, several groups on the West Coast, including Hess, Freden, and White of the Lawrence Radiation Laboratory, Karplus of the University of California, and Dessler of the Lockheed Laboratory, have reëxamined the contributions from solar injection and neutron beta decay as competing sources for the electron population of the outer belt. The tentative conclusion is that the detailed features of the outer belt are more readily explained by the beta decay source than by solar injection. Furthermore, it appears that the measured flux of neutrons in the atmosphere is sufficient to account for the observed intensity of outer zone particles. The neutron flux measurement was completed by Hess, using detectors carried piggy-back on Atlas flights. On the basis of these flux data, Hess carried out extensive calculations on the rate of leakage of neutrons from the atmosphere into the outer Van Allen region. From the leakage rate, he further computed the production rate of electrons by neutron beta decay, the efficiency of trapping in the magnetic field, and the energy spectrum of the trapped electrons. He reported to the Planetary Sciences session that the flux of electrons above 50 kev, calculated in this way, is within an order of magnitude of the observed fluxes, thereby confirming that beta decay is, indeed, an adequate source of particles for the outer belt.

It must be noted that the problem of accounting for the large changes in the trapped particle population following solar activity is still a vexing one for the proponents of the neutron beta decay theory. Karplus and Dessler reported an ingenious suggestion at the meeting, whereby solar activity modulates the intensity of *observable* electrons in an indirect manner. They point out that the detectors flown thus far in space vehicles can respond only to relatively energetic electrons. They suggest that trapped electrons of low energy, produced by neutron beta decay, are always present in large and substantially unchanging numbers in the outer zone, but with the bulk of the electron population below the detector threshold. They reason that at the time of a solar

disturbance, the resulting perturbations of the geomagnetic field may produce local accelerations that substantially increase the number of electrons above the detector threshold. In this way they account for the correlation between solar activity and the detected population of the outer zone.

Certain aspects of the beta decay theory have been the source of some dispute. In particular, there is disagreement over the rate at which the electron population at low energies is depleted by scattering in the atmosphere. The calculations by Hess indicate that the spectrum will extend below 50 kev, whereas P. J. Kellogg finds that depletion will be substantial below 300 kev. There is also disagreement over the correct order of magnitude for the representative fluxes of electrons in the outer region. Holly and Johnson have reported fluxes of 10^8 electrons/cm^2/sec as typical, and these are in agreement with yields calculated from the neutron beta decay. However, Van Allen finds representative fluxes of 10^9 electrons/cm^2/sec which are too large to be accounted for by the beta decay source. It is clear that further experimental and theoretical study will be necessary to settle these questions, but it is also clear that the work of Hess and other advocates of the beta-decay theory will have a very stimulating effect on research in this field.

The program also included a report by Freden and White on recent work related to the properties of the inner Van Allen zone. Their results were obtained by analysis of nuclear emulsion stacks flown through the lower edge of the inner belt just before and after the major solar flare of May 10, 1959. Proton fluxes on the two flights differed by only 20%, indicating that the solar flare had little influence on the proton population of the inner belt. Since solar activity is known to affect the activity in the outer belt, although the mechanism involved is still under dispute, it appears that there can be only negligible transfer of particles between the two belts. This result confirms the earlier findings of Van Allen in the Argus Experiment, and strongly suggests that the particles in the inner belt are born within that region, presumably by the beta decay of cosmic ray neutrons.

Freden and White did not find the alpha particles which would be expected if solar streams were the source of the inner belt. They have also calculated the energy spectrum of the trapped particles in the inner belt on the basis of the beta decay hypothesis, and find good agreement between their calculated spectrum and their observed energy distribution, in further confirmation of the beta-decay source for the inner zone.

The session on Meteorites opened with an interesting discussion by Fisher on the difference in ages between the iron and stone meteorites. The iron meteorites are usually dated at some hundreds of millions of years by their content of cosmic ray-induced tritium. The stone meteorites, on the other hand, have cosmic ray ages of the order of tens of millions of years. H. C. Urey has pointed out that the apparent youth of the stones may be understood if they have been buried beneath the surface of an object such as the Moon, and therefore not subjected to cosmic ray bombardment. Accordingly, Urey has suggested that objects of lunar size accumulated in the infancy of the solar system, and that a subsequent disintegration or surface ejection produced the stone meteorites. However, the work of Fisher indicates that when the depth dependence of cosmic ray-induced radioactivity is taken into account, the cosmic ray ages of both irons and stones become so uncertain as to remove the previous discrepancy between these two groups of objects. According to Fisher, it is no longer possible to state definitely that the irons and stones have had a different origin or history.

E. L. Fireman and J. DeFelice of the Smithsonian Astrophysical Observatory reported the results of an investigation into the variation of cosmic ray intensity within the solar system. The investigation was carried out on a sample of the recently fallen Hamlet chondrite, a meteorite which fell in Indiana on October 13, 1959. A parallel investigation on the Hamlet chondrite was also reported by Schaeffer, Stoenner and Davis of Brookhaven. The analysis of the Hamlet chondrite is based on a comparison of the abundances of the relatively short-lived argon 37 with the long-lived argon 39 isotope. Since argon 37 has a half-life of approximately 35 days, it can only be produced by cosmic radiation near the Earth, that is, at a solar distance of one Astronomical Unit. Argon 39 has a lifetime of 260 years, and moving in the ec-

centric orbits presumed to be representative of the asteroidal belt, it samples cosmic ray intensities at appreciably greater distances from the sun than one Astronomical Unit.

The results of both groups indicate the ratio of argon 37 to argon 39 in the Hamlet meteorite is approximately three times greater than would be expected if the intensity of cosmic rays were constant throughout the solar system. Accordingly, the intensity of cosmic radiation falls off with increasing distance from the Sun.

The discovery of unexpectedly intense emissions from Jupiter in the radio region has stimulated a number of experimental and theoretical investigations in recent years. A report presented by Warwick and Lee in the session on Planetary Atmospheres on the emission from Jupiter between 15 and 35 megacycles, indicates that the spectrum of this radiation varies greatly from day to day, and also shows strong short-period fluctuations for the duration of the order of 10 seconds. A clue to the origin of the radiation appeared in the data obtained during one interval of exceptionally intense emission in February 1960, in which Warwick and Lee observed an unusual drifting of the peak energy across the spectrum. The peak energy moved within one half hour from 15 megacycles to the upper limit of their scan at 35 megacycles. A preliminary interpretation, based on the shift from low to high frequencies, suggested that Jupiter's emission in this frequency region is produced by synchrotron radiation from highly relativistic electrons. These electrons are presumably trapped above the atmosphere in a Jovian magnetic field. As in the case of the terrestrial Van Allen zones, the trapped energetic electrons may be generated in the outer atmosphere by an acceleration process when solar plasma clouds impinge on the Jovian field; or the electrons may be conveyed to Jupiter in these clouds.

Jupiter is also a strong emitter of radiation at decimeter wavelengths. G. B. Field of Princeton University has carried out an extensive theoretical analysis of the decimeter radiation from Jupiter, following an earlier suggestion by Drake and Hvatum that the source of this emission might be cyclotron radiation from electrons trapped in a Jovian Van Allen belt. According to Field, his calculations indicate that the observed intensity of the decimeter emission from Jupiter can be explained by a reasonable density of trapped electrons, of the same order of magnitude as has been recorded under representative conditions in the outer Van Allen zones of the earth. However, the field strengths required to produce the observed frequencies are very large. It is, in fact, necessary to assume a polar magnetic field of approximately 1000 gauss on the surface of Jupiter, in order to account for the decimeter emission.

It is possible that so strong a field as this may be produced on the major planets by the same mechanism of internal convection that is assumed to be its source within the earth. Unfortunately, the implications of a theoretical analysis by DeMarcus of the structure of Jupiter would appear to be inconsistent with the assumption of substantial Jovian convection currents. According to De Marcus, 84% of the mass of Jupiter consists of solid hydrogen in a high pressure metallic state. He points out that the thermal conductivity of metallic hydrogen is expected to be very large, and therefore all the heat of radioactivity generated within the interior of the planet can be transported to the surface by a very modest temperature gradient. The estimated temperature gradient is, in fact, less than adiabatic, and is therefore inadequate to drive a convection current. Thus, we must look to another source for the magnetic field on Jupiter. In this connection, Field observes that the metallic phase should also have a very high electrical conductivity, which would inhibit the decay of any primordial field existing within Jupiter during the early history of that planet. He estimates that the primordial field of Jupiter will last for five eons, provided the temperature at the core is less than 800° Kelvin.

Some objections may be raised to this very interesting model. It seems unlikely that a temperature as low as 800° can be maintained within the interiors of any of the planets over an interval of several eons. Moreover, recent spectroscopic observations by Zabriskie, also reported in the Planetary Atmospheres session of this program, indicate a surprisingly low concentration of hydrogen in the atmosphere of Jupiter. It appears that a substantial amount of the primitive atmosphere may have, actually, escaped from Jupiter, in which event DeMarcus' analysis of the structure of Jupiter may require extensive revisions.

The presentation of the first results from the Pioneer V space probe was one of the highlights of the Planetary Sciences program. The Pioneer V instrumentation included a combination of particle detectors and a sensitive magnetometer which made it uniquely valuable for the study of the interplanetary plasma.

This particular combination of instruments is important because the interplanetary gas is highly ionized, and an ionized gas carries its magnetic field around with it. We can best understand what is going on in the gas if we measure both the magnetic field and the plasma flux at the same time.

The problem of solar-terrestrial relationships, and in particular the determination of the mechanism for the transfer of particles between sun and earth, is one of the outstanding problems in geophysics at the present time. For this reason the magnetometer-plasma detector package is an experiment of the greatest importance; it constitutes a major scientific accomplishment for the US space research program.

The magnetometer carried on Pioneer V was a search coil with a sensitivity estimated at better than one gamma, designed and constructed by Coleman, Judge, Smith and Sonett at the Space Technology Laboratories. The preliminary data from the Pioneer V magnetometer contain several features of interest. First, they indicated a departure from the expected geomagnetic field strength as the instrument passed through a region at a geocentric distance of approximately 10 Earth radii. The sign of this perturbation suggests an equatorial ring current circling the Earth in a zone between 7 and 13 radii. The Van Allen radiation belts which occur at lower altitudes consist of relatively high energy particles. The STL group suggests that the ring current detected by the magnetometer may be associated with particles having too low an energy to be observed by detectors flown in our satellites and probes thus far.

Second, Pioneer V indicated a zone of disturbance in the magnetic field at a distance of some 10 to 15 Earth's radii, suggesting that the interplanetary boundary of the Earth's field is substantially farther from the Earth than had previously been proposed. These boundary field fluctuations presumably are associated with the interaction between the geomagnetic field and an extremely soft component of the solar plasma. The particle detectors on Pioneer V were not sensitive to energies as low as those that we believe to be important in this particular zone, and a proper description of the field-particle interaction will only come with later flights containing both magnetometers and particle detectors with suitably low thresholds.

Third, the measurements of the interplanetary field indicate a 'quiet' value of approximately two gammas, on which there are superposed small fluctuations related presumably to the propagation of gas clouds through the interplanetary medium. At the time of the unusually intense solar storm on March 31, 1960, the interplanetary field displayed a remarkable increase to values in the neighborhood of 40 gamma.

Hoffman and Winckler reported that the ionization chamber and geiger counter in Pioneer V detected substantial particle fluxes during the same period in which the magnetometer readings indicated the large increase noted above. These effects were accompanied on Earth by major Earth current disturbances, a North Atlantic communications blackout, and auroral displays. Cosmic ray counters also indicated a large Forbush increase in that period. Counting rate increases were observed in a series of balloon flights in Minneapolis, and finally, the Earth satellite Explorer VII showed substantial changes in the trapped particle belt in the same interval.

The increases in flux observed by Winckler and his collaborators range up to 10 times the galactic cosmic ray background. The observed ion to count ratio corresponds to an E^{-4} differential energy spectrum, with a lower limit of about 40 mev.

Explorer VII data reported independently of the AGU program by Van Allen and his collaborators indicated a 10 to 40 fold increase in the electrons in the kev region, in the outer zone on April 2–7, 1960, in the period just following the storm detected by Pioneer V. Winckler concludes that these increases in the outer zone cannot have been produced by direct solar injection, since the flux observed by Pioneer V in space was only 10^{-4} of that appearing in the outer zone. However, it is possible that a closer examination of the trapping mechanisms and the calculations of the times for trapping may

be required before we can be certain of this conclusion.

The rejection of the solar injection mechanism for the formation of the outer belt confirms the independent analyses by Freden, White, and Hess, and the theoretical conclusions of Karplus and Dessler. It is too early to regard these conclusions as other than tentative, but it must be said that the hypothesis of solar injection no longer holds its previously dominant position among the possible hypotheses for the formation of the outer zone.

Pioneer V also contained a coincidence counter arrangement developed by J. A. Simpson, C. Y. Fan, and P. Meyer, identical with that used in Explorer VI. These detectors are sensitive to energetic electrons and protons, and also give a measure of the bremsstrahlung from electrons and gamma rays of lower energies. On 31 March 1960, the energetic particle count showed a decrease of the Forbush type in the galactic cosmic ray intensity at a distance of 5×10^6 km from the Earth. The decrease at this distance was at least as great as that at the Earth, and in this simple result Simpson and his collaborators prove invalid the theories of the Forbush decrease, which require the presence of the Earth and its magnetic field. In fact, it is now certain, as a result of these preliminary data, that the Forbush decrease is associated with magnetic-field changes in the interplanetary medium and spread throughout the solar system.

Another important fact reported by Simpson is that polar-cap absorption of radio noise, as communicated by H. Leinbach to Simpson privately, was found to occur simultaneously with the increase of particle flux measured at the position of Pioneer V. The simultaneity of these variations demonstrates that the solar-flare particles which produce ionization in the polar atmosphere are not stored either in the geomagnetic field or at the Sun.

Montana Earthquakes Noted in Pennsylvania Mine-Water Pools

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A recent paper by daCosta [1959] reported water-level fluctuations caused by the Montana earthquake of August 18, 1959, and mentioned the fluctuations registered in three mine-water pools of the Northern anthracite field in northeastern Pennsylvania, ten miles north of Wilkes-Barre. This paper will discuss the water-level phenomena of these pools in more detail.

Most of the coal mines near Wilkes-Barre are idle, and ground water is forming extensive mine-water pools in the underground mine openings. Some of the pools are interconnected by boreholes, tunnels, and other openings through the barrier pillars between adjacent mines.

The area is underlain by consolidated sediments of Mississippian and Pennsylvanian age, and unconsolidated sediments of Quaternary age. The rocks consist of sandstone, shale, conglomerate, coal, boulders, gravel, sand, silt, and clay. The structure of the Northern anthracite field is a large, northeasterly trending, synclinorium that has been completely folded and faulted. About 12 coal beds have been wholly or partially mined in the area. Continuous water-level recorders were installed in three mine shafts to record the rise of the water level in three separate mine-water pools underlying the area between Wilkes-Barre and Pittston, Pa.

All three recorded the major shock wave of the Montana earthquake as a vertical line rising above and falling below the normal trace inked on the chart. The recorders are driven by spring clocks and are set to traverse a 9.6-inch chart in eight days, or 0.1 inch in two hours. Consequently the arrival time of the shock wave cannot be determined precisely from the chart. Additional limitations in the accuracy of the record are caused by the size and weight of the float, weight of the counterbalance, length and type of wire, and gear system. These conditions result in a considerable reduction in the amplitude of the recorded wave. The data obtained from the water-level recorders are presented in the following table. The earthquake was reported by the U. S. Coast and Geodetic Survey to have occurred at 06 37 13 GMT and the fluctuations on the recorder chart occurred between 02h30m and 03h30m EDT (06h30m–07h00m GMT).

	No. 7 Shaft Ewen Mine	Red Ash Shaft No. 14 Mine	Red Ash Shaft Henry Mine
Maximum Rise of water level in Feet. (as read from recorder chart)	0.08	0.10	0.03
Maximum Decline of water level in Feet. (as read from recorder chart)	0.05	0.07	0.02
Double Amplitude (in feet)	0.13	0.17	0.05
Gear Ratio	1:10	1:5	1:5

The mine-water pools in the anthracite mines are unconfined bodies of water. The water is restricted in movement by barrier pillars between adjacent mines. The numerous interconnected mine workings extend from the outcrops down the dip to the center of the structure, and afford routes along which the water can flow and form underground pools. The occurrence of water in the mines, therefore, is unlike the water confined in an artesian aquifer in that shorelines in the outcrop area and shafts are openings with a free air-water surface.

The shock-wave front from the Montana earthquake approached the structure at approximately right angles. The initial shock along the northwestern flank may have caused the structure to decrease in volume as the result of a compressional stress, so that the water level in the pool rose. As the shock wave passed through and across the structure a corresponding decrease in water level was recorded owing

to the removal of the stress. It is possible also that the phenomenon was manifested by a seiche in the pool. However, the sensitivity of the instrument could not pick up the oscillatory effects from resonance so commonly reflected on lakes, streams, and bays that have been subjected to earthquake shocks. Such effects if present would have been damped by the complicated structure of the pool.

Reference

DaCosta, Jose A., Water-level fluctuations caused by Montana earthquake, *Trans. Amer. Geophys. Union*, 40, 346, 1959.

Review

A. P. MAZURAK (ed.), *Soviet Soil Science*, American Institute of Biological Sciences, Washington, D. C. (a translation), $40.00 per year.

Soviet Soil Science is an English translation of the Russian journal *Pochvovedeniye*, published by the Academy of Sciences of the USSR in Moscow.

This 'cover-to-cover' translation of the Russian scientific monthly is part of a project of the AIBS, supported by grants from the National Science Foundation.

Pochvovedeniye was founded in 1899. It carries no volume numbers. The issues of each year are numbered from 1 to 12. Translation begins with the January 1958 issue (1958, no. 1).

Each issue of *Pochvovedeniye* consists of several parts. The first part is made up of articles dealing largely with the general or basic problems of soil genesis, geography, and classification as well as soil physics and soil chemistry. Usually, this part is a little more than half of the whole issue. The second part is devoted to "scientific information and the study of methods." It includes somewhat shorter papers dealing predominantly with technical problems of soil investigations and various practical problems of soil use by man. The next three parts—*Discussions, Book Reviews,* and *Chronicles*—are shorter and rather irregular. Usually, each consists of one to three items, and a single issue of the magazine seldom includes all three sections. The last part is devoted to a bibliography of the world literature on soil science, occupying from 10 to 15 printed pages giving the information in the original and Russian languages.

As an example, let us compare the English version of the June 1958 issue printed in February 1960, with its Russian counterpart (1958, number 6). The translation comprises 115 pages of the 136 pages in the original. More than half of the difference in number of pages (about 13 pages out of 21) is due to omission of English summaries, which accompany virtually all long and short Russian articles, and the omission of the greater part of a bibliography of current literature. The bibliography printed in the June 1958 issue of *Pochvovedeniye* occupies 14½ pages and lists 317 titles, including 192 papers in foreign languages (English, French, German, and others). The non-Russian titles, accompanied by Russian translations, occupy about 8½ printed pages, but these are omitted in the English translation of *Pochvovedeniye*. This is hardly justifiable for a cover-to-cover translation. Readers of the translation might get the impression that Russian soil scientists are interested only in literature in their own language and ignore foreign contributions.

The June 1958 issue of *Pochvovedeniye* includes nine papers in the first part (pp. 1–79) and nine shorter papers in the second part (pp. 80–120).

The leading article (by Remezov) deals with certain aspects of the long and short geochemical cycles of elements. It is followed by a discussion (by Kats) of the types and distribution of bogs in cold and temperate belts of the northern hemisphere. The third paper (by Lebedev) deals with the principal factors of base exchange in soils; the fourth (by Muratova) with the accumulation of salts in soils and ground water; the sixth (by Pokhiton) with the influence of forest vegetation upon soils; the eighth (by Nadezhdin) with some peculiar local soils in the southern part of the Mid-Siberian Platform. The shorter articles of the second part deal with such subjects as determination of the exchange capacity of soil colloids; vertical migration of nitrates in certain Chernozems; evaluation of methods for determining moisture content at wilting; amelioration of sod-podzolic soils by barn manure and mineral fertilizers, and the types of soil-and-water relationships. These random items are listed here as an illustration of the wide scope of interest of the journal and its contributors.

The English translation of this issue of *Pochvovedeniye* and particularly its editing leave much to be desired. Errors and defects are scattered throughout the issue.

For example (many more might be cited), a portion of the third paragraph on page 580 contains three errors: (1) The phrase ". . . the clinker-brick wall laid *on clay-mortar*" is translated as ". . . fire-clay brick wall on *top of the exposed clay*. . . .", (2) the phrase ". . . a pipe was mounted at a right angle to the inclination of the surface of the impermeable-to-water clay . . ." is rendered as ". . . A tube *acting as a water barrier* . . . was mounted at the right angle to the vertical line from the clay surface . . .", (3) the phrase ". . . 20 cm. wide blade was welded . . . to the pipe . . . in order to prevent the trickle of solution under the pipe . . ." is translated as ". . . a belt 20 cm. wide was welded below the crack . . . this . . . *provided a means of escape* for a trickle of solution under the tube . . .". On page 613 is another serious error in translation. The phrase ". . . precipitation from juvenile thermal springs" in the second paragraph on page 613 is translated as ". . . discharges to deep thermal *energy sources*. . . ."

The list of large and small errors could be extended for several pages. The defects which are pointed out above, however, should suffice to justify the requirement of much more careful

editing of the translation before it goes to press.

The issues of the Russian journal are available to everyone who is interested in them. Virtually all articles in them are accompanied by English summaries. It is true that these summaries are very short and are written in poor English. We would appreciate it if they were at least double their present length. But even so, an English reader unfamiliar with the intricacies of the Russian language might get fairly clear ideas as to what these articles are about. Should he find something of special interest, he would be able to secure a translation of the entire paper or any part of it. This might raise a question, then, as to the justification for a cover-to-cover translation of issues almost two years old.

C. C. Nikiforoff

List of Recent Books of Interest and Importance to Geophysicists

AHRENS, L. H., FRANK PRESS, KALERVO RANKAMA, AND S. K. RUNCORN, *Physics and Chemistry of the Earth*, vol. 3, Pergamon Press, New York, 453 pp., 1959, $15.00.

AMERICAN SOCIETY FOR TESTING MATERIALS, *Standards on Methods of Atmospheric Sampling and Analysis: Methods of Testing, Recommended Practices, Definitions*, Am. Soc. for Testing Materials, Philadelphia, 102 pp., 1960, $2.25.

ANDERSON, CHARLES E., (ed.), *Cumulus Dynamics*, Pergamon Press, New York, approx. 304 pp., 1960, $12.00, (Proceedings of the First Conference on Cumulus Convection).

BATCHELOR, G. K., (ed.), *The Scientific Papers of Sir Geoffrey Ingram Taylor*, vol. 2, *Meteorology, Oceanography, and Turbulent Flow*, Cambridge Univ. Press, New York, 525 pp., 1960, $14.50.

BLAKE, RALPH M., CURT J. DUCASSE, AND EDWARD H. MADDEN (eds.), *Theories of Scientific Method: The Renaissance through the Nineteenth Century*, University of Washington Press, 346 pp., $6.50 (Investigates scientific concepts through five centuries of Western thought).

BUCHHEIM, ROBERT W., and others, *Space Handbook: Astronautics and Its applications*, Random House, New York, xvi + 330 pp., 1959, $3.95.

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The Hydrometeorological Service of the USSR on the Fortieth Anniversary of the Great October Socialist Revolution; LC or SLA, mi $3.90, ph $10.80 [*Meteorologiya i Gidrologiya* (*USSR*), no. 11, 1957] (collected papers).

Notes and Personalia

Notes

• CORRIGENDUM—In the June 1960 issue of *Transactions*, p. 311, the addresses of the co-authors of the report on Ground Water by Philip E. LaMoreaux and George B. Maxey were interchanged. The address of Mr. LaMoreaux is U. S. Geological Survey, Washington 25, D. C. Mr. Maxey, Chairman of the AGU Committee on Ground Water, is at Illinois State Geological Survey, Urbana 1, Illinois.

• CORRIGENDUM—In the March 1960 issue of the *Transactions* it was stated that Bradford Willard is studying the Bassler library at Lehigh University. The NSF grant is for a study of the large Bassler collection of South American fossils.

• INTERNATIONAL INDIAN OCEAN EXPEDITION—Of the readily accessible areas of the Earth, perhaps less is known of the Indian Ocean than of any other like area. The Special Committee for Oceanic Research (SCOR) of the International Council of Scientific Unions (ICSU) has thus chosen this area as one for major scientific investigation over the next few years. Twelve nations have announced plans to provide ships and scientific parties to undertake cooperative investigations, studying physical oceanography, chemical oceanography, meteorology, marine biology, studies of the ocean bottom, and in general broad surveys in geophysics. It is anticipated that as many as 20 vessels and 350 scientists will be at work in this expedition. The White House has announced that the U. S. will lend its support to the nation's leading oceanographic institutions in this expedition, which is now getting under way. The Navy Department will make available to these institu-

tions various oceanographic ships, and the National Science Foundation is planning and coordinating the federal support of the program. Beyond the quest for greater knowledge of the Earth on which we live, the expedition has many practical implications. The location of shoals and regions of up-welling will identify likewise fishing areas; and studies of the distribution, nature, and seasonal variation of the organic materials and marine organisms will indicate the type of fish and provide estimates of fish population. Thus, the problem is important from the standpoint of food supply. The meteorological information will be of great help in the understanding of the phenomena over the Earth, and bear especially on the forecasting for nearby areas. Ocean bottom studies may reveal resources of economic importance. Furthermore, the studies should attract students to the field of oceanography and assist in relieving what is now a world-wide shortage of marine scientists. The estimated direct cost of the operation is about $6,500,000.

• OCEANOGRAPHIC EXPEDITION TO SOUTHWESTERN PACIFIC AND SOUTHERN INDIAN OCEAN—The earlier planned track of the Expedition 'Monsoon' of the Scripps Institution of Oceanography has been modified to include more extensive investigations of the southern and central Indian Ocean, prior to the large-scale cooperative International Indian Ocean Expedition, 1960–64, proposed by SCOR, and to which 'Monsoon' will be the Institution's initial contribution. The program covers a period from August 1960 to February 1961, and will cover approximately 35,000 miles of track in the Indian Ocean and southwestern Pacific. The Expedition is using a 1900-ton Navy ARS converted research vessel. Besides sediment studies, geological and geophysical investigations will be made in the Indian Ocean.

• NATIONAL SCIENCE FOUNDATION OBSERVES TENTH ANNIVERSARY—George B. Kistiakowsky, Science Advisor to the President, gave the major address at a dinner held on May 12 in observance of the 10th anniversary year of the National Science Foundation. The organic act establishing the Foundation was signed by President Truman on May 10, 1950. Since then it has rapidly increased its value and effectiveness in support of basic research, and encouragement and support of scientific education and training, its two major responsibilities. The Fellowship program is the oldest support program, having begun in fiscal 1952 by giving 533 doctoral and 38 post-doctoral fellowships; in fiscal 1959, 3937 fellowships were awarded to recipients ranging from secondary school teachers to senior post-doctoral scientists. Since 1952, approximately 13,000 graduate students and advanced scholars have been so aided. For training teachers and keeping them abreast of developments the Foundation's Institutes program of courses is offered at colleges and universities throughout the country; in 1959, 31,000 took advantage of these services. For support of basic research, 746 grants, totalling $23,723,424, in the physical sciences (including mathematics and engineering), 967 grants, totalling $20,461,605, in the biological and medical sciences, and 53 grants, totalling $889,300, in the social sciences were made in 1959. Other activities include improvements of facilities for performing basic research at institutions by providing funds for construction of costly instruments and installations; maintenance of the research facilities in the field of astronomy; making grants (on a matched-funds basis) for modernizing and equipping graduate laboratories; support of services for translating foreign journals; support of a Science Information Service office within its organization; coordinating scientific information activities of the Federal Government; appraisal of research and development as factors in U. S. economic life; and formulating recommendations for a national science policy. The AGU has been aided greatly by grants from NSF for publications and scientific conferences.

• GOVERNMENT AIDS WORLD-WIDE PROGRAM IN SEISMOLOGICAL RESEARCH—Under Project Vela of the Department of Defense, modern standardized seismic equipment will be provided for 125 stations throughout the world, as part of a broad program to further research in seismology. This program follows recommendations of the Berkner panel on seismology, consisting of Perry Byerly, Univ. of Calif.; Carl Kissinger, St. Louis Univ.; Jack Oliver, Columbia University; Frank Preas, California Institute of Technology; and James T. Wilson, Univ. of Michigan, (chairman). The world-wide standardized seismographic instrument part of the program will be administered by the U. S. Coast and Geodetic Survey.

The instruments will be calibrated to record waves over a range of periods from about 0.1 to 100 seconds. The aim is to provide a cooperative seismographic net in which completely standardized equipment will be used, giving new and more quantitative data for studies of seismic activity throughout the world, as well as of the mechanisms of earthquakes and the propagation of seismic waves.

Inquiries relating to the program, and requests for copies of the first report of the NAS-NRC Committee on Seismological Stations should be sent to the Coast and Geodetic Survey.

• ATOMIC POWER PLANTS IN ANTARCTICA—In late June the Atomic Energy Commission began soliciting bids for the construction of three small atomic power stations for the National Science Foundation research bases near the South Pole. Because the cost of a suitable conventional fuel—diesel oil—runs as high as $10 per gallon, it is estimated that a saving of $60 million dollars over a 20-year span, the life of the reactors, will be realized. It has been pointed out that the stations will not only provide useful information on the technology of reactors, but will also add greatly to U. S. prestige.

• INTERNATIONAL SPACE ACADEMY—The International Astronautical Federation and the Daniel and Florence Guggenheim Foundation will finance

the first three years of an International Academy of Astronautics, formation of which was authorized at the 1959 London meeting of the Federation. Theodore von Kármán, Honorary Member of ASCE, and an outstanding astronautical scientist is chairman of the Founding Committee. The new Academy is designed to provide technical leadership for the peaceful conquering of space, and to serve as a center for information on astronautics.

• METEOROLOGICAL ROCKET NETWORK—A governmental report to the Space Science Board of the National Academy of Sciences gives details of a meteorological rocket firing network recently developed. This procedure will provide data for altitudes of more than twice those afforded by radiosonde balloons.

• WORLD'S LARGEST SOLAR TELESCOPE TO BE BUILT AT KITT PEAK OBSERVATORY—According to a National Science Foundation announcement the World's largest telescope will be built at Kitt Peak National Observatory. Plans call for completion in approximately two years. The instrument will permit solar study in much greater detail than is now possible, and in addition to spectral studies will enable us to learn much more about sunspots, and solar 'flares'. The need for greater scientific knowledge of the Sun was emphasized in a report of the National Academy of Sciences. Kitt Peak Observatory is one of two major astronomical facilities supported by the National Science Foundation, which has granted $4 million for the Kitt Peak solar program.

• VEHICLE FOR EXPLORING OCEAN FLOOR—The U. S. Navy reports that a remote control undersea vehicle for studying the ocean floor has been developed for the Office of Naval Research. Known as RUM (Remote Underwater Manipulator) the vehicle is essentially a tank equipped with a long, jointed, manipulator arm and hand and specially devised underwater television cameras. The vehicle is linked to a mobile van on shore by a long cable to permit operations to five miles from shore. It can operate down to depths of 20,000 feet at a speed of three miles per hour on level bottom; it can also operate on grades of 60% and can climb a vertical obstacle 12 inches high. The present vehicle was built primarily to test its feasibility for oceanographic research.

• DISCOVERY OF MINERAL COESITE HAS SPACE IMPLICATIONS—According to an announcement from the U. S. Geological Survey the mineral *coesite*, recently identified in sheared sandstone from Meteor Crater, Arizona, by E. C. T. Chao may be significant of temperature and pressure conditions resulting from meteor impact, not only on Earth, but on the Moon. Samples of rock from the Moon may, indeed, become a reality in the not so distant future. Solution of the mechanics of impact of a meteorite and of the energy released, as indicated by coesite has a direct bearing on the recognition of impact structures, and on the origin of lunar craters, as there is strong evidence that many of them are of impact, rather than volcanic origin. It suggests the beginnings of what might be called 'space geology', the study of rocks on other planets and satellites, say Survey officials.

• EARTHQUAKES AFFECT WATER LEVELS OVER WIDE AREA—According to data analyzed by the U. S. Geological Survey the recent Chilean earthquakes caused water levels to fluctuate in wells in Hawaii, Puerto Rico, and continental United States from Florida to Wisconsin; the effects in continental U. S. were not so pronounced, however, as those of the Montana earthquake of August 29, 1959. In general, major earthquakes cause fluctuations that are detectable with automatic recorders and the data serve to furnish information on the structural properties of rock formations that affect their ability to yield water.

• INTERNATIONAL CLOUD PHYSICS CONFERENCE—The Division of Radiophysics of the Commonwealth Scientific and Industrial Research Organization, Commonwealth of Australia, and the Australian Academy of Science, are sponsoring the International Conference at Canberra, following the Tenth Pacific Science Congress in Honolulu, in September 1961. The program includes the following topics: Cloud Growth; Microphysics of Clouds—Condensation Nuclei: Freezing Nuclei—Ice Phase; Rain—Coalescence Process—Radar; and Cloud Seeding.

• EXPLORATORY DRILLING AT KILAUEA IKI—Continuing work by the U. S. Geological Survey team at Kilauea Iki has resulted in a penetration of approximately 13 feet into the newly formed crust following the November-December activity. Important new temperature data as well as tilt measurements are being obtained.

• PACIFIC SCIENCE INFORMATION CENTER—Aided by a grant from National Science Foundation, the Pacific Scientific Information Center has been organized at the Bishop Museum, Honolulu, for the purpose of furthering interchange of information on the natural history and geography of Pacific islands, especially as these concern Man's relation to environment. Files of geographical data, maps, and air photographs are being organized and expanded as an initial project. E. H. Bryan, Jr., Consultant in Pacific geography and bibliography for the Pacific Science Board of the National Academy of Sciences—National Research Council, and member of the Bishop Museum staff, is in charge.

• A NEW JOURNAL OF MAPS—Biogeography of the North Atlantic is proposed for publication by the American Geographical Society, working with a panel set up by the Committee on Oceanography of the National Academy of Sciences—National Research Council. This unusual kind of journal, tentatively called *North Atlantic Biogeography*, will consist of maps, with explanatory texts, and will appear irregularly as contributions are accepted. It will serve for publications of biological, geological, physical, and chemical studies that will promote knowledge and understanding of the marine environment. In scope it will embrace the

Atlantic north of the equator, and the Arctic basin.

• NEWSLETTER FOR MARINE SCIENCES—The UNESCO Science Cooperation Office for Southeast Asia is now publishing a mimeographed *Marine Sciences Newsletter*. The first issue, dated November 1959, contains a paper by Dr. Klaus Wyrtki on *Physical Oceanography in the Central Indo-Pacific Region*. The *Newsletter* is obtainable from the UNESCO Science Corporation office for Southeast Asia, P. O. Box 2313, Djakarta, Indonesia.

• GRANT FOR RESEARCH ON OCEAN TEMPERATURES DURING THE ICE AGES—The National Science Foundation has given $113,000 in grants to scientists at Lamont Geological Observatory and Amherst College for a joint research program on the determination of ocean temperatures during the last ice age. Deep-sea sediment cores at the Lamont Observatory will be studied, using the oxygen isotope method developed by Harold C. Urey and his colleagues at the University of Chicago. Bruce B. Benson, physicist at Amherst College, and David B. Ericson and Allan W. H. Be of Lamont Observatory share in the award; Robert J. Menzies, formerly of Lamont, and now Director of the Marine Biological Station at Caracas, Venezuela, will collaborate as a consultant.

• CRUISE OF THE RESEARCH VESSEL CHAIN—The research vessel *Chain* of the Woods Hole Oceanographic Institution started a 4½ month cruise on June 30 into northern European waters. Chiefly, studies will be made of ocean-bottom sediments, the sub-bottom, and the Earth's crustal structure. Routine observations will include continuous profiles of the bottom, sound velocities, and charting of upper water temperatures. Also, heat flow from the Earth's interior through the sediments will be measured. Bottom photographs, dredge hauls, and seismic reflection tests will also be made. J. B. Hersey will be chief scientist for part of the cruise.

• CANADIAN POLAR BASIN STUDIES—A Canadian expedition including oceanographers, topographers, geologists, geophysicists, and geographers, has begun a systematic study of the little known arctic continental shelf. This year the area covered extends 250 to 300 miles out onto the shelf ice, from a base line that extends from Meighan Island to Borden Island.

• REPORT ON EXPEDITION TO HALLEY BAY, ANTARCTICA—The Royal Society of London has announced publication of a discussion on the results of its expedition to Halley Bay, Antarctica, a project of the International Geophysical Year. The discussion was held on February 4, 1960. The report includes nine contributions relating to seismology, glaciology, meteorology, the ionosphere and ionospheric drifts, aurora, and geomagnetics. It is published as *Proceedings of the Royal Society, Series A*, volume 256, part 1285. The cost is 18s, + 1s for postage and packing.

• ARMY POLAR EXPEDITION—A special Army Polar Expedition, known as Project Lead Dog, has left Camp Tuto, near Thule, on an 1800-mile trip over the Greenland icecap to Crown Prince Christian Land and Peary Land. It includes scientists of the Chemical Corps, Medical Corps, Signal Corps, Quartermaster Corps, Engineering Corps, and Air Force Cambridge Research Center.

• ATLAS AND DATA FOR PACIFIC OCEANIC OBSERVATIONS—The University of California Press announces publication of a series, *Oceanic Observations of the Pacific*. The first volume, April 15, 1960, consists of *The NORPAC Data Volume* and *The Norpac Atlas*. The second volume, April 15, 1960, contains data for 1950 cruises; in preparation are volumes for pre-1949, 1951, 1955, and 1958.

• TSUNAMI WARNING REPORT—The special Tsunami Warning System Review Committee of the Geophysical Society of Hawaii (Mid Pacific Regional Group of AGU) has submitted its comprehensive review of the warning system now in use. The study was carried on for more than a year. The report was presented for discussion at a meeting of the Society held on July 6, in Honolulu. Officials of the Hawaiian Academy of Science have praised it highly for its constructive suggestions as well as its comprehensiveness, and its public service. The report has contributed appreciably to public understanding of the problems, and the needs for, and requirements of, effective warning systems.

• EARTHQUAKE STUDIES IN CHILE—A team from the Earthquake Engineering Research Institute and the California Institute of Technology made a two-week study, in June, of the effects of the recent Chilean earthquakes on structures. The project was financed under a National Science Foundation grant. Particular attention was given to the characteristics and action of the sea waves caused by the quakes. James N. Jordan of the U. S. Coast and Geodetic Survey was a member of the team. Close liaison was maintained with seismologists and earthquake engineers in Chile, among them Pierre St. Armand, a geologist from the California Institute of Technology, who is spending a year in Chile with the Institute of Inter-American affairs. A report on this investigation will be published in the Bulletin of the Seismological Society. On the basis of this report further studies may be made.

• AWARDS UNDER THE FULBRIGHT ACT—Announcement has been made of the availability of awards for university lectureships and advanced research, 1961–1962, under the Fulbright and Smith-Mundt Acts. Additional information and application forms are obtainable from Conference Board of Associated Research Councils, Committee on International Exchange of Persons, 2101 Constitution Avenue, Washington 25, D. C. The closing date for applications is October 1, 1960. Twenty-six countries are involved in the program for 1961–1962.

• INDUSTRIAL BASIC RESEARCH INCREASES—According to statistics released by National Science Foundation funds expended by private industry for basic research in 1958 amounted to $296 million, an increase of 96% over 1953. Total perform-

ance in research and development in 1958 was $8.2 billions, of which Federal financing provided $4.6 billions.

• EXPENDITURES FOR RESEARCH BY COLLEGIATE INSTITUTIONS SHOW MARKED INCREASE—The National Science Foundation reports that expenditures of funds for research in the natural and social sciences increased 80% between 1954 and 1958. In 1938, more than half of the $735.8 million of such 'earmarked' funds was spent by agricultural experiment stations and the Federal contract research centers administered by educational institutions. Overhead costs were found to be 28% of the direct costs.

• SCHOLARSHIPS IN EARTH SCIENCES ESTABLISHED AT MIT—The Massachusetts Institute of Technology has announced a gift of $1,250,000 from Mr. and Mrs. Eugene McDermott of Dallas, Texas, for establishment of scholarships in Earth Sciences for students from southwestern states in geology, geophysics, meteorology, and oceanography, or allied fields. About twenty four scholarships will be awarded for 1960–1961, and twelve or more thereafter to incoming freshmen.

• UNDERGRADUATE SCIENTIFIC RESEARCH PROGRAMS—The National Science Foundation has announced that about 2500 students, supported by 330 grants, have worked or will be working alongside scientists of more than 200 research organizations during the summer and current school year. This is part of the Foundation's Undergraduate Research Participation and Undergraduate Research Training programs.

• SOIL AND WATER ABSTRACTING SERVICE—Colorado State University Research Foundation has received a NSF grant for effecting a world-wide comprehensive abstracting and indexing service in the field of soil and water. The foundation solicits listing to receive publications that contain research papers dealing with these fields.

• INTERNATIONAL GROWTH SYMPOSIUM AT PURDUE UNIVERSITY—More than 2100 scientists from all parts of the world attended the International Symposium on Growth held at Purdue University, June 16–18, 1960. Of direct interest to Earth scientists was the program of the last day which contained sessions relating to soil science. Hans Jenny, University of California, speaking on *Plant Root-Soil Interactions*, discussed the role of contact exchange in the movement of ions from soil particles into plant roots. M. B. Russell and J. T. Wooley, University of Illinois, in their topic *Transport Processes in the Soil-Plant System*, considered basic aspects of fluid transfer in soils and plants. C. E. Marshall, University of Missouri, in his topic *Colloid Chemistry of the Soil in Relation to Plant Nutrition*, discussed the relationship of mean activity of ions in the soil to nutrient uptake and growth of plants such as soybeans. A. G. Norman, University of Michigan, spoke on *The Biological Environment of Roots;* he not only considered the soil as a habitat and substrate for micro-organisms, but also took note of the changes that occur in this habitat and substrate as plant roots invade it. The contributions of the various speakers will be published in a *Symposium Proceedings* by Basic Books, Inc., 59 Fourth Ave., New York, at a price not to exceed ten dollars. Dale Swartzendruber of Purdue University was AGU's representative of the Symposium.

• GRANTS FOR FOREIGN GEOGRAPHICAL RESEARCH—The National Research Council will conduct its sixth annual program of geographical field research in foreign areas in 1961, under financial sponsorship of the Office of Naval Research. The object is to strengthen American Geography by stimulating greater participation in areas outside the English-speaking areas of North America, Hawaii, Bermuda, and the Bahamas. Projects in physical geography are specially encouraged, but consideration will be given to all branches of geography and closely related fields. The program is designed primarily for graduate students, but post-doctoral applicants will also be considered. Requests for further information, and applications, should be addressed to Foreign Field Research Program, Division of Earth Sciences, 2101 Constitution Avenue, Washington 25, D. C. Applications for support of field work that is to be started before April 1, 1962, must be submitted before December 1, 1960 .

• WATHEROO MAGNETIC OBSERVATORY, established in 1919 by the Carnegie Institution of Washington at a site 110 miles north of Perth, Western Australia, and later given to the Australian Commonwealth Government, has been transferred to Mundaring, near Perth. Correspondence should be addressed to Mundaring Geophysical Observatory, Mundaring, Western Australia.

Personalia

• PHILIP H. ABELSON, Director of the Geophysical Laboratory of the Carnegie Institution of Washington, and Co-Editor of the *Journal of Geophysical Research*, has been appointed a member of the General Advisory Committee of the U. S. Atomic Energy Commission. He was one of the early pioneers in atomic energy, and was the first man in this country to identify uranium fission products.

• LEONIDAS T. BARROW of Houston, Texas, has been named an honorary member of the American Association of Petroleum Geologists.

• LLOYD V. BERKNER, President of the American Geophysical Union, was elected Treasurer of the

National Academy of Sciences for a four-year term at the 97th Annual Meeting of the Academy. As a member of the Council of the Academy he will share responsibility for the general conduct of the Academy and its National Research Council, and accordingly in its activities in the stimulation of basic and applied research, which now accounts for an annual expenditure of more than $12,000,000.

• JACOB A. BJERKNES, Professor of Meteorology at the University of California (L. A.), and Bowie Medalist for 1945, has been elected a fellow of the American Academy of Arts and Sciences.

• HENRY G. BOOKER, Professor of Electrical Engineering at Cornell University, has been elected to the National Academy of Sciences.

• J. M. BURGERS of the Institute for Fluid Dynamics and Applied Mathematics, University of Maryland, attended the international conference sponsored by the Mathematics Research Center of the U. S. Army, at the University of Wisconsin, in June.

• PERRY BYERLY, Professor at the University of California (Berkeley), has been awarded a Fulbright Scholarship. He is engaged in a lecture and research program at Cambridge University, England, in the Department of Geodesy and Geophysics. He expects to return to the United States in February 1961.

• ALBERT P. CRARY, Supervising Physicist, Cambridge Research Center, Bedford, Mass., has received the Department of Defense Distinguished Civilian Service Award for his research in polar areas.

• FARRINGTON DANIELS, Emeritus Professor of Chemistry, University of Wisconsin, recently on tour of the Far East, addressed the Asian Foundation at San Francisco in May on observations and problems in the Far East.

• EDWARD C. DAPPLES, Professor of Geology at Northwestern University has been awarded a Senior Visiting Fellowship in Science of the Organization for European Economic Cooperation, at the Universities of Lausanne and Geneva, Switzerland. The program is administered by the National Science Foundation.

• RICHARD F. FLINT, Professor of Geology at Yale University, has been elected a fellow of the American Academy of Arts and Sciences.

• HERBERT FRIEDMAN, Naval Research Laboratory, has been elected to membership in the National Academy of Sciences, and to fellowship in the American Academy of Arts and Sciences.

• SAMUEL S. GOLDICH, formerly Professor of Petrology at the University of Minnesota, is now with the United States Geological Survey, in Washington, D. C.

• BERNARD HAURWITZ, Professor of Astro-Geophysics at the University of Colorado, has been elected to membership in the National Academy of Sciences.

• HOLLIS D. HEDBERG, Professor of Geology at Princeton University, has been elected to membership in the National Academy of Sciences.

• W. A. HEISKANEN of Ohio State University has received an honorary doctor's degree from Uppsala University, Sweden.

• HANS G. HERTZ, formerly with Army Map Service, is now associated with the Goddard Space Flight Center of NASA.

• B. G. HOLZMAN, Brig. General, U. S. Air Force, formerly in charge of the Air Force Office of Scientific Research, and former President of the Section of Meteorology, AGU, is now commander of the Air Force Research Division. This unit includes the European Office of the Air Research and Development Command, the Aeronautical Research Laboratory at Wright-Patterson Air Force Base in Ohio, the Geophysics and Electronic Research Directorates at Bedford, Mass., and other Air Force research elements.

• R. E. JENTOFT of the California Research Corporation has been appointed Senior Research Chemist at the Richmond Laboratory of that organization.

• GEORGE C. KENNEDY of the Institute of Geophysics, University of California (L. A.), has been elected to fellowship in the American Academy of Arts and Sciences.

• PAUL F. KERR, Professor of Mineralogy at Columbia University, was recently awarded an honorary degree by Occidental College, Los Angeles.

• A. I. LEVORSEN of Tulsa, Oklahoma, has been named an honorary member of the Society of Economic Paleontologists and Mineralogists because of his many contributions to geologic science.

• JOSEPH KAPLAN, Professor of Physics at the University of California (L. A.) received the Exceptional Service Award, highest decoration given by the Air Force, for his leadership in geophysics.

• WALTER LANGBEIN of the U. S. Geological Survey attended the meeting of the Symposium on Arid Lands, held at UNESCO House, Paris, May 11 to 18, 1960.

• LUNA LEOPOLD, Chief Hydraulic Engineer, U. S. Geological Survey, and U. S. Member of UNESCO Advisory Committee on Arid Zone Research, presented a paper on the *Uses of Limited Water Supplies* at the General Symposium on Arid Lands, held at UNESCO House in Paris, May 11 to 18, 1960.

• THEODORE A. LINK, President of Cree Oil Co., Ltd., of Canada, recently was awarded the Blaylock Memorial Medal from the Canadian Institute of Mining and Metallurgy.

• GEORGE A. LLANO has been appointed a science specialist, Science and Technology Division, Library of Congress.

• KIRTLEY F. MATHER, Professor (emeritus) of Geology at Harvard University, has been re-elected to the presidency of the American Academy of Arts and Sciences for the fourth year.

• STJEPEN MOHOROVICIC of Zagreb, Yugoslavia, world-renowned geophysicist, seismologist, and mathematician, became 70 years old on August 20, 1960. Variously a teacher, researcher, and di-

rector of scientific laboratories, he retired from formal duties in 1952, but since that time has been active as a private scholar in various fields of physics and geophysics. Among geophysicists and geologists he is particularly famous for his studies and theories relating to the compositions and physical characteristics of the Earth's shells, to seismologic measurements, and to the sources, transmission, and interpretation of earthquake waves.

• GROVER E. MURRAY, Professor of Geology at Louisiana State University, has been re-elected editor of the Society of Economic Paleontologists and Mineralogists.

• ERNEST J. ÖPIK, University of Maryland and Armagh Observatory, Ireland, has been awarded the J. Lawrence Smith medal of the National Academy of Sciences for his investigations of meteors.

• EDGAR W. OWEN of San Antonio, Texas, has been named an honorary member of the American Association of Petroleum Geologists.

• EMANUEL R. PIORE, Director of Research of the International Business Machines Corporation, has been named Chairman of the company's Research and Development Board.

• FRANK PRESS, Director of the Seismological Laboratory of California Institute of Technology, represented the United States at a conference in Geneva, May 12, 1960, for discussions of a research program to improve detection and identification of underground nuclear explosions.

• JOHN C. REED has retired from the United States Geological Survey and is now Executive Director of the Arctic Institute of North America, at Montreal, Canada.

• WALTER ORR ROBERTS of the High Altitude Observatory, Boulder, Colorado, has been named first Director of the new National Research Center for Atmospheric Research established under a NSF grant of $500,000 to the University Corporation on Atmospheric Research (UCAR). It is expected that the new research group will collaborate closely with university scientists, and provide facility management for what may become a large and widely dispersed research program. He was also elected recently to the National Academy of Arts and Sciences.

• CARL F. ROMNEY, Assistant Technical Director, Office of Atomic Energy, Department of Defense, represented the United States at a conference in Geneva, May 12, 1960, for discussions of a research program to improve detection and identification of underground nuclear explosions.

• WILLIAM W. RUBEY retired September 7, 1960 from the U. S. Geological Survey, and is now on the staff of the University of California, at Los Angeles. He was recently awarded an honorary Doctor of Science degree by Yale University. He has been appointed to the National Science Board by President Eisenhower for a term of six years.

• RICHARD J. RUSSELL of Louisiana State University has received an Outstanding Achievement Citation of the Association of American Geographers.

• PAUL B. SEARS, Chairman of the Conservation Department at Yale University, retired on June 30.

• LAURENCE L. SLOSS, Professor of Geology at Northwestern University, is the new Vice-president of the Society of Economic Paleontologists and Mineralogists.

• ROBERT STONELEY, University of Cambridge, England, attended the international conference sponsored by the Mathematics Research Center of the U. S. Army at the University of Wisconsin in June.

• RICHARD N. TOUSEY, Physicist, and Head of the Rocket Spectroscopy Branch at the U. S. Naval Research Laboratory, has been elected to membership in the National Academy of Sciences.

• JAMES A. VAN ALLEN of the State University of Iowa has been awarded an honorary Doctorate by Northwestern University.

• JEROME VAN DE ERVE, Chairman of the Pacific Southwest Inter-Agency Committee and Department of Commerce adviser to the California-Nevada Interstate Compact Commision has been elected General Chairman of the Western Snow Conference.

• ERNEST H. VOLWILER, President and General Manager of Abbott Laboratories, has received the American Institute of Chemists' Gold Medal for "Outstanding contributions to the pharmaceutical industry and . . . great service as a leader in the chemical profession." Among the lines of research under his direction was that on the barbiturates, and the development of pentothal.

• JEROME B. WIESNER, Director of the Research Laboratory of Electronics at the Massachusetts Institute of Technology, has been elected to membership in the National Academy of Sciences.

• JAMES T. WILSON, Professor of Geology, University of Michigan, attended the inauguration of Judson William Foust, new President of Central Michigan University, on April 25, as official representative of AGU.

• CLIFTON THORNE BARKER, Engineer and Consultant with the Tennessee Valley Authority and formerly Chief of the River Transportation Division, died on June 8, 1959. He was born in St. Paul, Minnesota, on May 17, 1898. He graduated from the Univ. of Minnesota in 1922, with the degree of Engineer of Mines. In 1924 he joined the U. S. Corps of Engineers at Chattanooga, Tenn., working on the Tennessee River Survey. In 1928 he became Assistant Engineer and was assigned to the Missouri River unit for studies on flood control, irrigation, navigation, and power. He was later promoted to Associate Engineer, and in April 1933 was transferred to the newly established Tennessee Valley Authority, first at Muscle Shoals and later at the Knoxville headquarters. He became Chief of the River Transportation Division in 1935. For reasons of health he was re-

lieved of administrative duties in January 1946 and took on special staff assignments as a transportation specialist. He contributed articles to various journals in his field. He had been a member of AGU since 1945.

• PAUL BARTSCH, Curator (Emeritus) of Mollusks at the Smithsonian Institution, and a world-wide authority, died at his home, Lebanon, in Lorton, Virginia, on April 24, 1960, at the age of 89. He was a native of Silesia, Germany, and came to this country with his parents in 1882, settling in Iowa. He graduated from the University of Iowa in 1896, received the Master of Arts degree there in 1899, and the Doctor of Philosophy degree in 1905. He came to the Smithsonian Institution in 1896. He taught histology at Howard University Medical School for 37 years, and began teaching also at George Washington University in 1900, introducing the subjects of botany and biology to the curriculum; he also started the University's graduate work in natural sciences. On his retirement from George Washington University he was awarded an honorary doctorate. He was author of more than 500 articles in the field of natural history. He joined the AGU in 1934 and became a Life Member in 1950.

• ERNEST F. CARMICHAEL, Hydraulic Engineer with the Soil Conservation Service, died in Spartanburg, South Carolina, on March 19, 1960. He was born in Lambertville, New Jersey, July 17, 1905. He graduated from the University of Delaware in 1928, with a degree in Civil Engineering. In 1933, he was appointed Camp Engineer and, later, Camp Superintendent for CCC camps, under the SCS. In 1941 he was transferred to Texas as hydrologist, and was assigned to the Hydrology Section at Fort Worth in 1944. In 1954 he was transferred to Spartanburg, S. C., as hydrologist for the Engineering and Watershed Planning Unit for Southeastern States, serving as supervisor and consultant for hydrologists of that unit. He made numerous contributions to the SCS Hydrology Handbook. He became a member of AGU in 1952.

• JAMES MULLIN HOWE, for 22 years in charge of the U. S. Weather Bureau in Charlotte, N. C., died on May 8, 1959, at the age of 63. He was born in Northfield, Vermont, and after graduating from high school there, received his first training in the local Weather Bureau station. In 1926 he was assigned to the Ithaca, N. Y., station as Observer, and in 1928 was placed in charge of the Oswego, N. Y., station. In 1937 he was transferred to Charlotte as Meteorologist in Charge, where he pioneered with radio and television forecasting. He had been a member of AGU since 1946.

• CHARLES T. LEEDS, MAJOR, U. S. ARMY (ret.), Director and Vice President of Leeds, Hill, and Jewett, Los Angeles, died in Pasadena, Calif., on March 20, 1960, at the age of 81. He was born in Newton, Massachusetts, and graduated from the U. S. Military Academy in 1903, taking a baccalaureate degree from Massachusetts Institute of Technology in 1906. He had served as consultant on many notable projects, including the Colorado River Aqueduct. He was an expert on beach erosion, and consulting seacoast engineer for the State of California. At one time he was District Engineer for the Los Angeles District of the Corps of Engineers. He had been a member of the American Geophysical Union since 1934.

• HOWARD THOMAS ORVILLE, Captain, U. S. Navy (ret.), Vice President of Beckman and Whitley, San Carlos, Calif., died May 24, 1960, at his home in Long Green, Maryland. He was born in 1901, in Saratoga, Wyoming. He retired as aerologist in the Navy in 1950, and later served as Chairman of President Eisenhower's Advisory Committee on Weather Control, a subject of major interest to him. He took a prominent part in developing the nation's wartime aerological services, and established a global network of weather stations. He was one of the first to recognize the importance of radar for obtaining weather data. In large measure through his efforts were developed the methods for locating and tracking hurricanes, a development that has resulted in practically eliminating loss of life in the United States due to these storms by providing advance warning of their paths and approach. He also proposed a national radar warning system for tornadoes and other violent storms. He was a past president of American Meteorological Society, and, shortly prior to his death, had resigned as the chairman of AGU's Committee on Corporation Membership. His honors included the Legion of Merit, Commendation Ribbon, American Defense Service Medal, Military Order of the British Empire, and the Order of the Cloud Banner, Third Class (China). He had been a member of AGU since 1947.

• MARTIN J. POLLAK, Senior Scientist with the Inter-American Tropical Tuna Commission, and Research Associate of the Scripps Institution of Oceanography of the University of California, died suddenly at his home in La Jolla, California, on June 5, 1960, at the age of 44. He was born in Vienna, Austria, and entered the United States in 1924. He received the A. B. degree from Harvard in 1938, studied briefly at New York University, and received the M. A. degree from Johns Hopkins in 1953. As Ensign and Lieutenant (JG) in the U. S. Naval Reserve, 1944–1947, he was engaged in hydrographic surveying in the Pacific Ocean. He was on the research staff of Woods Hole Oceanographic Institution during 1940–44, and 1947–51, one of his duties being to lead a Mediterranean cruise of the *Atlantis* that resulted in a notable paper by Pollak on the deep water in the Mediterranean. From 1951 to 1958 he was on the research staff of Chesapeake Bay Institute of Johns Hopkins University, and his papers published during this period cover a variety of topics in physical oceanography. Since December 1958 he had been engaged in research, under the auspices of the Tuna Commission, on the physical and chemical oceanography of the Eastern Tropical Pacific Ocean, with particular reference to the surface and subsurface circulation. During November-Decem-

ber 1959 he led a cruise on the research vessel *Horizon* to study the dynamics of the Costa Rican thermal dome and was engaged in the analysis of the resulting data at the time of his death. He had been a member of the American Geophysical Union since 1947.

• FRANK H. WATSON, JR., of Lodi, Calif., died in Lodi on July 4, 1959. He was born in Biggs, California, March 4, 1899. He attended the College of Agriculture of the University of California, and for 11 years engaged in agricultural pursuits, chiefly farm management. In 1930 he became Superintendent of Woods-Robert Island Irrigation and Drainage District. For 28 years he was connected with the East Bay Municipal Utility District, and since 1930 was in charge of the hydrological investigations of the Makelumne River Basin, chief source of water supply for the District. He had been a member of AGU since 1951.

• WALTER N. WHITE, retired, for 37 years an engineer with the Water Resources unit of the U. S. Geological Survey, died at Morganton, N. C., on May 28, 1960, at the age of 83. He was born in Rochester, Wisconsin, and went to California as a young man, graduating from Leland Stanford University with the degree of Civil Engineer. After graduation he joined the Geological Survey staff in Washington, D. C., but his field work took him into most of the western states. Before and during World War II, he was in charge of groundwater studies in Texas, and worked in close collaboration with the State Board of Water Engineers. He had a citation from General Jonathan Wainwright for his assistance in locating Army camps. On his retirement from Government service in 1948 he was awarded the Interior Department's Gold Medal for distinguished service. For a time he continued to work with the State Board, and also established a consulting practice. He was author and co-author of many Government publications, chiefly in the field of ground water; one of his best-known works was a report on "Evaporation and Transpiration of Water in Plants." He became a member of AGU in 1935.

Union, Section, and Committee Activities

Minutes of Executive Committee Meeting, American Geophysical Union First Session, April 25, 1960

The meeting was called to order at 09h 40m in Room 5042 of the Building of the Department of Commerce, Washington, D. C., by President Lloyd V. Berkner.

Present—P. H. Abelson, L. H. Adams, Frederick J. Agnich, L. T. Aldrich, Leroy R. Alldredge, Lloyd V. Berkner, Walter H. Bucher, Perry Byerly, Earl Droessler, C. T. Elvey, Irving Friedman, H. Richard Gault, Harry H. Hess, Floyd W. Hough, Patrick M. Hurley, Woodrow C. Jacobs, Robert Jastrow, James N. Jordan, J. W. Joyce, Joseph Kaplan, Eugene C. LaFond, Walter D. Lambert, Helmut E. Landsberg, John Lyman, Mark F. Meier, Leonard M. Murphy, J. H. Nelson, Alfred O. C. Nier, Hugh Odishaw, James A. Peoples, Jr., Charles Pierce, D. W. Pritchard, John C. Reed, F. W. Reichelderfer, Mrs. Ethel Sanders, A. Nelson Sayre, J. Frank Schairer, Alan H. Shapley, A. C. Simonpietri, L. P. Slichter, Waldo E. Smith, E. H. Vestine, Charles A. Whitten, Ralph N. Wilson, and George P. Woollard.

Approval of minutes—The minutes of the Executive Committee meeting held on November 14, 1959 and published in the March 1960 issue of the *Transactions* (pp. 54–68) were approved.

General Secretary's Report

The last report of the General Secretary is recorded in the minutes of the Executive Committee meeting of November 14, 1959, published in the March 1960 issue of the *Transactions* (pp. 54–58). There have been no changes in the Executive Committee in the interval since the last meeting although, as noted later, a number of Chairmen for new Special Committees have been appointed.

Actions of Executive Committee by mail ballot—Since the last meeting of the Committee, two lists (10th of 1959 and 1st of 1960) of new members and three new corporation members have been approved by the Executive Committee by mail ballot. A second list for 1960 of proposed new members is now in process and will be transmitted within a few days.

The matter of the extension of the Russian translation project to include *Goedesy and Cartography* and *Meteorology and Hydrology* also received favorable action, although some felt that the problem was too complex to answer on a "Yes" or "No" basis or that possibly some other journal (*Doklady*) should receive next consideration. While the approval was overwhelming, an opportunity to discuss these matters will be given in due course.

Since the last meeting of the Committee, a grant of $5000 has been received from the National Science Foundation for the purpose of aiding us in the preparation and publication of the Triennial Report to the Twelfth General Assembly of IUGG.

Publications—The *Journal of Geophysical Research* has gone forward at approximately monthly intervals though some issues have been somewhat delayed by the compounding of a number of factors. The April issue, however, due to be complete on April 7 was in fact actually complete on April 6. It appears that we are now approximately on schedule again. The November issue contained a Symposium on the Exploration of Space based on the symposium by the same title presented at the meeting of the National Academy of Sciences last spring. The symposium is being reprinted by Macmillan Company to be available as a book. The December issue of the *Journal* included the International Symposium on Fluid Mechanics in the Ionosphere which was presented by the U. S. National Committee of URSI at a meeting held at Cornell University in July 1959. This issue contained over 450 pages, our largest to date. The total for the calendar year 1959 was almost 2500 pages. The February 1960 issue contained the International Symposium on Electronic Distance-Measuring Techniques presented at a meeting of the International Association of Geodesy and sponsored by AGU which was held in Washington last spring during and immediately following our annual meeting. These have all been well received. A summary of the issues from November 1959 through April 1960 is shown in the accompanying table. The total number of subscriptions, both through membership and special subscriptions, continues to grow.

Issue	Text pages	Unnumbered pages	Paid advertising	Edition
Journal of Geophysical Research				
Nov. 1959	390	2	2	9400
Dec. 1959	452	12	6½	9400
Jan. 1960	384	8	6	9600
Feb. 1960	414	10	7½	9600
Mar. 1960	284	8	5½	9600
Apr. 1960	248	8	8	9600
Transactions				
Dec. 1959	110	10	2	9200
Mar. 1960	122	6	2	9100

The *Transactions* have been issued quarterly. The December 1959 and March 1960 numbers have appeared since our last meeting. Information concerning these is set forth in the table.

The June 1960 issue will contain the triennial report to the IUGG on geophysical developments in the United States. This is a new undertaking of which Leason Adams was invited to act as Editor. Some 70 reports have been received and are now in the hands of the printer. It is anticipated that about 1500 copies of the complete report and a limited number of Section or Association reports will be sent to Helsinki for distribution there. We have had the cooperation of the U. S. Coast and Geodetic Survey in the design and printing of the cover. It is believed that the Report will be a very effective and distinctive contribution of the United States to the success of the Helsinki meeting.

Each issue of the *Transactions* has continued to carry three *IGY Bulletins* which are being preprinted for the U. S. IGY group. Publication of the *Bulletin* may be discontinued with the June 1960 issue. Plans for replacing this with a somewhat similar bulletin relating to the Space Board or the work of the new Committee on Geophysical Research are still indefinite, although AGU has indicated willingness to cooperate in such endeavor as outlined at the last meeting of the Executive Committee. If such plans cannot be worked out, the *Transactions* will be markedly decreased in size (about 48 pages) starting with the September issue.

The translation of the first eight numbers of the 1959 series of *Izvestiya* of the Academy of Sciences, USSR, Geophysics Series, is complete and copy is in the hands of the printer. The composition of the first two has been completed by the printer, and these issues should be released before May 1. The schedule calls for the completion of the 12 numbers of 1959 by July 1960.

An application is being made for funds to translate and publish the English edition of *Izvestiya* for the 1960 series. This work is continuing under the able direction of W. S. Jardetzky, the Translation Editor, who has organized an excellent panel of translators. The composition and printing of *Izvestiya* is being done for us by McGregor and Werner.

Although *Izvestiya* for 1957 has been completed, we are still awaiting a final reporting on this from Pergamon Press in order to effect final settlement.

The translation and publication of Nos. 37, 38, 39, and 40 of *Trudy* of the Geophysical Institute of Moscow are being undertaken for us by Consultants Bureau in New York. The first three of these are due for completion soon. No. 4 has been delayed by the issuance of a new edition of *Trudy* No. 40. It was deemed best to base our English translation on the new edition. This will result in a delay until about June 1.

At the meeting of the Russian Translation Board in January it was felt that, in the light of the fact that there are some 160 Russian Earth science journals, not to mention 60 or 70 from Communist China and substantial groups from other Iron Curtain countries, it was rather impossible to consider full cover-to-cover translation. Accordingly, the Board urged that steps be taken to develop an adequate geophysics abstract journal, worldwide in its scope. The Executive Secretary and the Chairman of AGU's Committee on Abstracting (John Lyman) were asked to explore this matter, and it was found that apparently an effective abstract journal is still some years away. In the meantime our view into the Russian activity in geophysics is limited to *Izvestiya* and, noting that in the biological sciences there are seven cover-to-cover translations and in physics a similar number, the proposition was recently laid before the Executive Committee by mail ballot to extend our cover-to-cover translations to include *Geodesy and Cartography* (highly recommended by the Section of Geodesy) and *Meteorology and Hydrology* (highly recommended by the Section of Hydrology) provided funds can be obtained. These were approved by the Executive Committee and we are awaiting approval by the Governing Board of the National Academy (approval required to receive the grants). Application for appropriate grants has been filed with the National Science Foundation. It is planned to arrange with a translating and composition company for undertaking this work. We will engage a translation consultant to check on the translations to be sure that they are of high standard. This is an attempt to develop a third potential facility for translating and publication.

Monograph No. 5, based on the Second Woods Hole Conference of our Cloud Physics Committee of the Section of Meterology, is scheduled for completion late in April. This has been delayed about two months largely because of the slowness of certain authors in transmitting their material to us in final form and by the fact that it is totaling some 450 pages, about 50% longer than we initially contemplated. An edition of 1300 has been ordered. The Conference and the publication of the results have been supported by a grant from the National Science Foundation.

This is the last of the monographs which we are undertaking without the guidance and direction of the Geophysical Monograph Board which has now been established under the chairmanship of Alan H. Shapley. The next monograph is not yet in view, but the Board has various plans under development.

Membership—Membership data as of April 12, 1960, are:

Membership as of November 2, 1959	5888
Reactivated	6
New members processed October 27, 1959 to April 12, 1960 (244 regular members, 143 student members), and 104 applications now being processed toward membership (81 regular members, 23 student mem-	

bers)	491	6385
Resigned	133	
Inactive	12	
Dropped	4	
Deceased (reported since November 2, 1959)	17	166
Total April 12, 1960		6219

Of these 231 are student members and 104 are life members.

Dues unpaid—As of April 12, 1960, the following dues were unpaid

Owe for 1960 (153 student members)	1182
Owe for part of 1960 (no student members)	14
Owe for 1959 and 1960 (no student members)	165

In addition, there are 115 persons who have not paid dues in full for 1958. According to the Statutes and By Laws, these are hereby recommended to the Executive Committee to be dropped from membership, but with the usual added recommendation that one more effort be made to return them to active membership.

With regard to the distribution according to Sections of those who have resigned (133 members) and those who are delinquent for 1960 dues (1029 members), most members have more than one affiliation. The 133 resigned, for example, had 305 affiliations and the 1029 delinquents have 2133 affiliations. The affiliations are distributed as shown in the following table. Also in this table is shown the distribution of affiliations of the total membership as of August 28, 1958.

Item	Resigned		Delinquent		Normal*
	No.	Pct	No.	Pct	Pct
Total	133		1029		
Total affiliations	305	100.0	2133	100.0	100.0
Geodesy	24	7.9	167	7.8	8.7
Seismology	40	13.1	254	11.9	12.7
Meteorology	34	11.1	339	15.9	15.2
Geomag. and Aeronomy	26	8.5	221	10.4	10.5
Oceanography	30	9.8	245	11.5	10.5
V., G. and P.	42	13.8	183	8.6	8.4
Hydrology	65	21.3	510	23.9	23.0
Tectonophysics	44	14.5	214	10.0	11.0
	305	100.0	2133	100.0	100.0

* Based on a membership of 5115, with 11,140 affiliations, as of August 28, 1958.

Deaths—The following 17 deaths have been reported to the office since our meeting of November 14, 1959: Charles R. Fettke, May 26, 1959; Robert Lee Lowry, May 31, 1959; Murry Hackman, July 12, 1959; Charles Stevens Partridge, September 1, 1959; Irving B. Crosby, September 18, 1959; Esme E. Rosaire, September 21, 1959; Omar O. Fickeissen, October 12, 1959; Harold S. Palmer, October 24, 1959; Sterling Price Fergusson, November 26, 1959; Ernesto Pichler, November 27, 1959; Ronald M. Wilson, November 28, 1959; James W. Baker, January 4, 1960; Abraham Streiff, January 4, 1960; Beno Gutenberg, January 25, 1960; Caleb Mills Saville, February 14, 1960; Arthur Louis Day, March 2, 1960; Penn P. Livingston (date unknown).

Finances—The assets of AGU as of April 1, 1960 are as follows:

Riggs National Bank, checking account	$ 3,091.20
Riggs National Bank, savings account	19,679.35
U. S. Series F Bonds (purchase price; mature value $700)	518.00
U. S. Treasury Notes, mature May 15, 1960	50,000.00
U. S. Treasury Notes, mature August 15, 1960	70,000.00
U. S. Treasury Bills, mature January 15, 1961	30,000.00
Northwestern Federal Savings & Loan Association	10,000.00
Prudential Building Association	9,691.16
Liberty Savings & Loan Association	1,441.97
Interstate Building Association	10,000.00
Enterprise Federal Savings & Loan Association	10,000.00
Eastern Building & Loan Association	10,000.00
Home Building & Loan Association	10,000.00
District Building & Loan Association	1,013.24
Jefferson Federal Savings & Loan Association	2,965.70
Total	$238,400.62

Below is an accounting of our assets as of April 1, 1960. Comparison is made with the two preceding years, but because of rapidly changing circumstances the comparison is without much significance.

	April 1, 1960	April 1, 1959	April 1, 1958
Current balance[a]	$119,324	$103,469	$39,402
Permanent Fund	21,222	17,587	14,589
Emergency Fund	1,000	1,000	1,000
T. M. & E. Award Fund	1,442	1,386	1,311
Russian Translation Fund			
Izvestiya, 1957	4,400	14,945	32,477
Izvestiya, 1958	14,098	41,414	.....
Izvestiya, 1959	43,524	.....	.....
Trudy	13,562	.....	.....

Cloud Physics Conference	6,651	24,583	.....
Conference on Contemporary Geodesy	4,547	5,991	.....
Monograph No. 3	1,131	.....	.....
Asia Foundation	2,500	.....	.....
IUGG Triennial Report	5,000	.....	.....
Totals	$238,401	$210,375	$88,779

* The total at this time of the year tends to give the wrong impression because most of our dues and subscription income for the year has been received and most of our expenditures are still ahead.

The budget as approved at the meeting a year ago was published on pages 260–261 of the September 1959 *Transactions* and has now been in effect for nine months. There are some rather sharp deviations from the budget, especially in the matter of publications. At the time of our meeting a year ago the *JGR* was publishing only about 100 pages per month, and it seemed that the goal of 2400 pages for 1959 and 3000 pages for 1960 would not be reached. The budget accordingly allowed $60,000 for the printing of *JGR*. By the time of our meeting on November 14, 1959 the picture had changed substantially and the goal had been reached and passed. This growth was recognized in the three-year outlook presented by the Budget Committee Chairman and was accepted by the committee, but the budget figure was not formally changed. The money was in hand for the increased number of pages from the grant of the National Science Foundation. Our expenditures for fiscal 1960 will be between $110,000 and $120,000. The tacit approval given in November might appropriately be formalized at this time.

Likewise the *Transactions* printing budget was set up as $5400 a year ago, the feeling being that the *Transactions* proper might be just a little news letter of 20 to 24 pages plus the *IGY Bulletins*. However, a need for an outlet on informative but non-scientific articles was felt, and at the November meeting the Executive Committee likewise approved in principle, though not in detail, the direction that the *Transactions* was taking. The total cost of the *Transactions* for the year, not counting the directory and not counting the *Triennial Report to IUGG* for which a special grant has been received from the National Science Foundation, will be on the order of $8000. Related items have likewise been affected. The Budget Chairman will supply the details at the appropriate time. The budget has been used by officers as a guide rather than as a straight jacket, feeling that this is essential to attaining the major purposes of AGU as long as the funds are available.

With regard to equipment, our budget allowance was $2000, but our expenditures will be in excess of $3000. Most of our equipment allotment for the last fiscal year was not used, and the General Secretary authorized its use during the current fiscal year in order (1) to equip two additional rooms, and (2) to modernize our operations to a limited extent. The overall picture is quite satisfactory.

The negotiable U. S. Treasury Notes and Bills that are the property of AGU are in the safe deposit box of the Riggs National Bank, Dupont Circle Branch.

In accordance with the recommendations of the Audit Committee in its report of last November approved by the Executive Committee, we have investigated the matter of modernizing AGU's system of bookkeeping. Garland C. Owens, Associate Professor of Accounting of Columbia University, has supplied similar counsel to the Arctic Institute of North America (whose budget is about four times as large as ours) and has recommended an exceedingly useful and effective plan with which the Institute is very pleased. He has indicated his willingness to undertake this task for us. His basic fee is $100 a day plus expenses, and he estimates that his services to AGU over a period of a year will cost us between $1500 and $2000. Also, he estimates that supplies and equipment necessary for the changeover will involve an expenditure of $500 to $800. It is recommended that we engage him to undertake this work. On the basis of the recommendations of last November, the Budget Committee has included funds to undertake this reorganization in the budget for fiscal 1961. It will be difficult to modernize fully our office operations by July 1 of this year, but the new system should be operating by January 1, 1961. Thus the first half of our fiscal year will be on the old system and the last half on the new system. Dr. Owens has indicated that no serious problems will be involved in the integration of the two into a single statement.

In connection with the preparation of the program of the Annual Meeting for 1960, the question arose as to whether we could print a special program for the sessions on planetary sciences which, because of circumstances, was completed after the general program was printed. Our program is 80 pages this year, and required the use of all the funds for the Annual Meeting. Granting that the printing of a special program for planetary sciences would have many advantages, we were stopped because of lack of funds. The amount involved was relatively small, perhaps between $250 and $350. The question was raised with persons in NASA, and it was indicated that possibly a fund could be made available from NASA to undertake special jobs such as this that might arise from time to time in order to provide greater latitude of operation for our new Planning Committee on Planetary Sciences. It seemed to the General Secretary to be within his prerogatives to accept such a fund without Executive Committee or other specific authority, but guidance and counsel is requested on this detail.

Office staff—The office staff at the present time

consists of four full-time employees on appointment to permanent positions, James J. Capello, Ethel G. Sanders, Carol C. Akers, and Judith M. Seek. Martha K. Potter, Tina Herrara, Elizabeth Lee Williams, and Theresa E. Phillips (Antioch College student) have been employed full time on a temporary basis to help handle the heavy workload of the office. Glenda Quinn Olmstead, who has been with us part time for six years, is still working three to four days a week, Dorothy S. Miller is working part time on proofreading, and Timothy O. Temple (a George Washington University student) is doing miscellaneous office work on a part-time basis.

In addition to the staff directly engaged in the office of AGU, there is an Assistant to the Editors doing the work of the mechanics of editing (Rowena E. Peoples) at Lawrence, Kansas; she uses the part-time services of a student. Also, through an arrangement made by Editor Abelson, the Carnegie Institution of Washington is supplying without cost to AGU the part-time services of Lucille Stryker to undertake additional work in the mechanics of editing.

Quarters—Our lease for our present quarters at the AAAS Building expired on June 30, 1959, and a new three-year lease has been entered into for the same quarters at an increased rate of $4.75 per square foot per year. The AGU rented two additional rooms on February 1, 1960, and we are now occupying eight rooms.

International matters—Chairman Joyce of the Committee on International Participation will report in detail later. The Committee held its last formal meeting on November 13, 1959, but in the interim there has been consultation by mail.

It appears that our total delegation to Finland will exceed 300, not including guests (foreign scientists and technologists in residence in the United States) and associates (family members), and U. S. participation should be very effective. The Academy will accredit somewhat over 100 delegates to the meeting, and the rest will be accredited by AGU.

A Symposium on Aeronomy will be held in Copenhagen the week preceding the opening of the Assembly in Helsinki, and apparently some 30 to 50 scientists from the United States will attend that meeting. This meeting has not been publicized particularly because it is still not known whether it is intended to be an invitational symposium.

Several of the Associations have been holding subject-matter conferences or symposia throughout the past months. The Association of Geodesy has been most active in this regard and has held a series starting with the one on electronic measurement of distances in connection with our annual meeting last year that have continued right up to recent days.

There has been some discussion of a plan to invite the IUGG to the United States, presumably on the West Coast, for the Assembly to be held in 1963. We will hear more about the details concerning this from Wallace Joyce, who also has under study matters relating to the reorganization of the U. S. National Committee and the Executive Committee of AGU.

Meetings—The AGU arranged for a series of sessions in connection with the annual meeting of the American Association for the Advancement of Science in Chicago in December. A committee under the chairmanship of John Simpson arranged for a two-session Symposium on the Upper Atmosphere, which was a highly successful meeting and quite well attended. A second committee cooperated with the committee of Section M of the AAAS for a three-session Symposium on the Great Lakes. The AGU committee was set up by W. C. Krumbein, who was out of the country at the time. Wallace S. Hamilton and M. B. Gamet served as co-chairmen. The first of the sessions was attended by about 200 persons, the second by about 125, and the third by about 75.

The Pacific Southwest Regional Group held its annual meeting at the University of Southern California on February 4–5, 1960, with about 200 participants. There was a very good program and most phases of geophysics, except the hard-rock phases, were included.

More than 300 papers have been offered for presentation at our 1960 Annual Meeting, about one-fourth more sessions than we have ever had before. As a consequence, we have as many as seven sessions occurring simultaneously. Our meeting rooms are in five different buildings. The State Department will have excellent conference facilities in another year which perhaps we may use and thus hold our meetings under one roof. If this does not become possible, serious consideration should be given to ways and means to accomplish this objective. I believe Chairman Abelson of the Committee on Meetings plans to discuss this matter later.

Also from time to time we have word that regional or local groups are interested, not so much in regional or local meetings, but rather in an occasional national meeting to be held outside of Washington. Should we attempt to hold our annual meeting in some other city or should we plan a second national meeting each year? These questions should be considered.

Statutes and By Laws—The recent ballot proposing the addition of a paragraph (g) to Article 3 of the Statutes to create various classes of Supporting Members was approved by an overwhelming vote as will be reported by the Committee of Tellers. However, apparently the statement was ambiguous in that it implies the way may be open for Supporting Members to designate more than one representative. The intent, of course, was that each Supporting Member would designate a single representative, and it is requested that the Executive Committee give formal approval to this interpretation.

No steps have been taken thus far to secure Supporting Members. Perhaps the President should initiate this by writing a letter to each of

our present Corporation Members, advising of this new situation and offering them the first opportunity to take out a higher grade of membership. Plans for developing this class of membership are under consideration by Chairman Droessler of the Membership Committee.

Upon the completion of the studies of Chairman Joyce of the Committee on International Participation relative to the reorganization of the U. S. National Committee of IUGG, substantial changes will be recommended with respect to the Statutes and By Laws. It is understood that Chairman Joyce is working closely with International Relations Director Atwood of the Academy and with others in developing the recommendations for changes. Following Executive Committee approval, the Committee on Statutes and By Laws will have a major task on its hands. This will also involve a provision for a Secretary for International Affairs as approved by the Executive Committee at its meeting on November 14.

The American Geological Institute reorganization committee has proposed a drastic reorganization contingent upon acceptance of this plan by the member societies of AGI. The committee proposes to change the Institute's name to Institute of Geological Sciences. Among many other changes, they propose to improve their financial stability by securing agreement of their member societies to add an assessment of 10% to the dues of each of their members for the support of IGS. Recognizing that two of their organizations (the American Institute of Mining, Metallurgical, and Petroleum Engineers, and AGU) have a large number of members who are not scientifically interested in geology, they are providing for an associate status. This also calls for an annual contribution to the Institute. Briefly reviewing our membership in AGI, it is pointed out that AGU affiliated with AGI chiefly as a gesture of moral support to an integration effort. However, there was no intent to attempt to bring all of geophysics under the aegis of geology. It has been pointed out that AGU and AGI are parallel organizations, that AGU is internationally affiliated with IUGG and the AGI with the International Geological Congress, and that on the national scene each is designed to integrate its own group of disciplines. It has further been noted that geologic interests of our members are appropriately represented in the AGI by their membership in geologic societies.

Miscellaneous—F. J. Agnich represented AGU at the inauguration of James Earl Rudder as President of Texas A & M College on March 26, 1960. James T. Wilson will represent AGU at the inauguration of Judson William Foust as President of Central Michigan University on April 25, 1960. Albert Stevens Fry is to be AGU's official representative at the inauguration of Andrew David Holt as the sixteenth President of the University of Tennessee on May 14, 1960.

The AGU has been asked to name a representative to attend the San Diego Conference of the National Conference on Teacher Education and Professional Standards of the National Education Association to be held June 21–24, 1960.

A. Nelson Sayre, *General Secretary*

Action on the General Secretary's report—The report was accepted.

Action on recommendations in the General Secretary's report—The recommendation that the persons who have not paid dues in full for 1958 and subsequently to be dropped from membership after making one more effort to return them to membership was accepted.

A motion was made and passed that:

> The interpretation of the new paragraph (g) to Article 3, recently approved by an overwhelming vote of the membership, that each supporting member should have but one representative.

President's Report

President Berkner had no formal report but noted that in the report of the Audit Committee approved at our meeting November 14, 1959, recommendation was made that we should employ the services of an accounting specialist to update our accounting methods so that effective cost accounting could be undertaken. He noted that in the last decade our budget has increased about tenfold to approximately one-third million dollars a year, and that we must make a careful accounting of funds. He noted that a Committee on Organization and Salaries had been designated under the chairmanship of the General Secretary and that the report of this Committee is complete for presentation at this meeting. In particular, financial data must be in suitable form so that the officers can evaluate the services provided by the Union in terms of the cost. He underscored the necessity for AGU both to be solidly organized and steadily evolving to meet the demands of growth in the geophysical sciences.

He also mentioned the importance of the Helsinki Meeting to be held this coming summer and that he has been impressed by the conscientious work of the individual sections. He believed that we are becoming well prepared for the forthcoming General Assembly.

He noted that the active work of the Union had required frequent discussion of policy matters underlining the need for the Officers to meet approximately on a monthly basis and that Vice President Reichelderfer has been frequently called upon in the absence of the President to aid in dealing with emergency matters. He then noted with regret that because of the press of duties and responsibilities to which commitments were made before undertaking the duties of Vice President, Vice President Reichelderfer has found it necessary to submit his resignation. This resignation was regretfully accepted and the General Secretary was instructed to prepare a letter on behalf of the Executive Committee and the American

Geophysical Union as a whole, expressing warm appreciation for the administrative council and effective service he has given to the Union, not only as Vice President, but in many other capacities as well, and to express the hope that he will continue to assist in the guidance of the Union.

The President instructed the Committee on Nominations to convene during the Annual Meeting and bring in their nominations for Vice President at the final Session of this Executive Committee meeting to be held Friday afternoon, April 29.

Reports of Standing and Special Committees

International Participation—Chairman Joyce had no formal report but noted that between 300 and 400 scientists and technologists will presumably comprise the U. S. delegation to the Twelfth General Assembly in Helsinki. Of these, 115 are NAS-NRC delegates selected on the nomination of the Union and its Sections. Letters have been sent by the National Academy of Sciences notifying them of their designation. Others will be designated as delegates of the American Geophysical Union.

Voting procedures are indicated in the letters to the NAS-NRC delegates, which group will meet in Helsinki on July 25 in a room to be assigned to the US delegation.

At the Helsinki Meeting, a small steering committee will be set up as in the case of the Toronto meeting. This will consist of Officers of the AGU and one member from each Association. This committee will meet daily or as necessary.

It was noted that the agenda of the Council of the IUGG was published in the IUGG Chronicle No. 25. Some items will require the development of an American position which will be discussed at the meeting of the delegates to be held April 30, 1960.

It was noted that the application of the Academia Sinica (Republic of China, Taipei) as a member of IUGG has been pending since 1957 and will probably be settled at the time of the General Assembly.

The modifications of the Statutes and By Laws to IUGG were circulated during the winter months and our report on suggested additions was transmitted to the General Secretary, dealing only on the major items. There has been indication that some National Committees may have become too greatly involved in details to the disadvantage of the main purposes of the change. The new Statutes provided for a seven-man Bureau, including the Treasurer.

At Helsinki, there will be discussion of establishment of additional permanent services, but the position taken by the Bureau of IUGG has been to proceed with establishment of these services only when it is clearly demonstrated that they are needed. Three of these suggested permanent services relate to Geomagnetism and Aeronomy: (a) World magnetic survey, (b) Air glow, and (c) Rapid variations. Another relates to bathymetric charts.

The publication problem of the IUGG is a very serious one. Now each Association has its own policy and the Union has an eighth. Past publications of value are lost since they do not receive general distribution and are not accessioned by libraries. In the interests of more effective utilization of the Union's resources, this must be changed and these brought into a more integrated and uniform pattern for regular circulation as scientific literature; but this can only be done through our representatives to the Associations. It must be understood that there is no intent to control scientific content but rather to develop a common format and a system that permits appropriate accessioning, cataloging and simple referencing, better distribution, and hopefully at somewhat reduced costs.

There is need to increase the budget of the IUGG. Increased income may be secured through increasing the unit subscription rate or by increasing the number of units in the various countries. It has been suggested that the subscription rate might be increased by 60%. Our annual dues to the IUGG are currently $4200.

It was noted that the Geodetic Association was established in 1863 and that there will be consideration of an appropriate means of celebrating the centenary in 1963, the year of the next General Assembly.

The suggestion has been made that the United States extend an invitation to the Thirteenth General Assembly as indicated in the minutes of the Executive Committee Meeting of November 14, 1959 [*Trans.*, 41, p. 60, Mar. 1960].

It was noted that elections will be held in IUGG as a whole and the various Associations, and appropriate consideration must be given to the matter of suitable candidates which we should support. It was urged that Section Presidents and representatives take this matter under advisement for subsequent report. It is important that men be selected who will further the purposes of the Union, and not simply hold office as an honorary gesture.

Chairman Joyce noted that the U. S. Embassy has issued a small publication on Finland that should be helpful to American delegates. He has written for permission to reproduce this or have copies supplied to us.

It is noted that a plan for the reorganization of the governing body of AGU had been published in the August 1958 issue of the *Transactions*, pp. 765–766. Since that time, additional information has been received and a revision of this will be discussed later in the meeting.

President Berkner noted that the US contributions to the programs in Helsinki are substantial and that many are outstanding. He feels that the Sections have done exceedingly well to get the best of our work in geophysics presented at the General Assembly.

The discussion of the Triennial Report was de-

ferred until after the arrival of Editor Leason H. Adams.

Publications—Editor Peoples noted that *JGR* has become increasingly recognized as the leading geophysics journal in the world. It now contains a great many papers of high scientific quality and has a very wide circulation (current edition of 9600).

Editor Abelson noted that the editors are constantly on the lookout for good symposia, assembled or unassembled, and that a Symposium on Spherics and Thunderstorms, to be presented before the Section of Meteorology, will appear in the July issue of the *JGR*. It was noted that the Pacific Science Congress, which is to be held in Hawaii in August 1961, is developing three sets of papers that will probably appear in the *Journal of Geophysical Research*—one in oceanography handled by Munk; one in meteorology by Palmer; and, one in space and upper atmosphere by Gordon MacDonald. He commented that the Ionospheric Conference held at Cornell in 1959 would probably have taken two years to publish commercially and would have sold for $20.00. We issued it in December 1959 and paper bound reprints are available for $4.50.

Editor Abelson further noted that from time to time the question has come up concerning lengthy tables. If the tables are a legitimate part of a paper but too lengthy to be published, he felt that the services of the American Documentation Institute should be used. He noted that the geomagnetic and solar data are to be condensed to occupy less space and that lengthy versions may appropriately be filed with the American Documentation Institute.

Editor Peoples called attention to the contribution of the Carnegie Institution of Washington of $2000 during the current calendar year, plus considerable assistance in the editorial processing of papers. A motion was made and approved that:

> The General Secretary be requested to write an appropriate letter to the Carnegie Institution of Washington thanking them for this valuable assistance.

With relation to the *Journal of Geophysical Research* a special problem has developed in hydrology. The former *Transactions* were approximately 40% hydrology. However, the hydrologists now feel that their material is lost in the greatly increased volume of material in the *JGR*, and there is considerable dissatisfaction and discussion of possible withdrawal of membership of some of our hydrologic members. It was felt that we should make a very serious and conscientious effort to secure many more of the fundamental papers in hydrology and that the *JGR*, being sent to a large circle of subscribers and members, reaches the largest number of geophysicists in all activities and thus would give full impact of the important field of hydrology and all other activities of geophysics.

The arguments to be used to secure these papers may be summed up as follows: (1) The wide circulation of the *Journal of Geophysical Research* (current edition of 9600, over 1500 of which go to overseas addresses); (2) the opportunity thus afforded to reach a wide circle of leading geophysicists of the world including the hydrologists; (3) fundamental papers have never been refused; the papers in hydrology are reviewed by a special committee of hydrologists; (4) very rapid publication, averaging about four months from receipt to publication; (5) scientists outside the field of hydrologic research want the opportunity to be informed of progress in the field, since hydrology reacts on other disciplines of geophysics.

There is no page limitation for hydrology or any other field although as shown in the March issue of the *Transactions*, a tentative budget of 500 pages was set up by the Editors, this being about 50% more than the number of pages published in the 1958 *Transactions* (the last year of the old bimonthly) or the *JGR* for 1959. We should have a journal that expresses geophysics across the board and this requires close collaboration between hydrology and other fields.

It was pointed out that to a lesser extent the same problem applies to oceanography and to a still lesser extent in meteorology, and that we should take steps in these fields likewise to be sure that they are appropriately represented in the *Journal of Geophysical Research*. It was noted that the very prompt publication plan (average four months from receipt to publication) is a great inducement to authors, noting that the average delay ranges from eight months to eighteen months in various other journals.

President Berkner noted that on the various trips he makes through the country he finds a very strong feeling that *JGR* as now constituted was serving a very useful purpose in integrating all aspects in geophysics and if we make any serious change we are likely to run into a furor from those who are presently well satisfied. He made a strong appeal for us all to work hard for the development of the *Journal of Geophysical Research* during these next months in an effort to bring in the best in all fields of geophysics and he suggested that we review this matter again a year hence with regard to hydrology. He noted that within five years hydrologists would be called upon to give consideration to the problem of the hydrology of the planets.

The motion was made and approved that:

> The Editors work closely with the Officers of each of the three Sections above cited and that these Sections should appoint committees, formal or informal as they see fit, in an effort to accomplish the aims of strengthening *JGR* in the scientific fields of Hydrology, Oceanography, and Meteorology.

President Berkner noted that the character of our journal is naturally influenced by the way that geophysics is developing and that the fields most active at a particular time are likely to be very

active in the way of publication. At the present moment this tends towards the outer atmosphere and space. AGU attempts to develop a synthesis and integration of all geophysical disciplines and while there will be differences of opinions as to emphasis, it has been the attitude of the Executive Committee over a long period of time that we should attempt in every way possible to bring the disciplines of geophysics more closely together for their mutual support and benefit, and especially their interaction and synthesis.

The Executive Secretary, who serves as Editor of the *Transactions*, reviewed the policy briefly, noting that a year ago we thought that the *Transactions* might become a 16- or 24-page newsletter, but that there seemed to be a broader need and with the tacit approval of the Executive Committee last November, the matter of this need has been undertaken so that we now publish papers not truly scientific in their character but rather on subjects bearing on geophysics of which geophysicists need firm knowledge. The *IGY Bulletin* as now funded may be terminated with the issuance of the June number but that there has been discussion with the Space Board and the Geophysics Research Committee of the National Academy for a continuation of some such publication. Discussions are actively in progress with Hugh Odishaw to work out a continuation of the current arrangement with the successor to the *IGY Bulletin*.

Triennial Report—Leason H. Adams, Editor of the Triennial Report to IUGG, which will appear in the June issue of the *Transactions*, indicated that he had had splendid cooperation from the authors (about 70) and from the various Section Officers in the compilation of the Triennial Report. This will be a sizeable document perhaps approaching 200 pages instead of slightly over 100 as earlier estimates had contemplated. He felt that the field had been covered quite adequately although there was considerable variation from author to author in the approach. This first report should be a guide for subsequent attempts and by this we can indicate more accurately what is expected. Also, the endeavor should start somewhat earlier than on this occasion.

Chairman Byerly, of the Russian Translation Board, reported on the problems of this Board as set forth in Appendix 1.

The Monograph Board report was deferred until the arrival of Chairman Alan Shapley.

There was discussion of the problem of developing worldwide and broad abstract journals in geophysics and also a word of caution regarding the duplication of translations. There was discussion of the tentative plan to translate the Russian periodical *Meteorology and Hydrology*, it being noted that select translations are being made by the American Meteorological Society. The meteorologists feel that cover-to-cover translation is not warranted. The Section of Hydrology has recommended cover-to-cover translation. It was agreed that there should be further discussion of this problem among the individuals concerned before application should be entered for funds for cover-to-cover translations.

Budget—Chairman John Reed presented the budget shown in Appendix 2. There was extensive discussion of this budget, including the discussion of the need for better accounting procedures which should involve a new method of presenting the budget. The motion was made and approved that:

> The budget presented be adopted as a guide until the new accounting procedures are developed.

The approval of the budget, as shown in Appendix 2, does not imply the approval of the individual items, for example, an increase in dues. (Action on increase in dues was laid on table until next meeting of the Executive Committee as noted later.)

The budget includes engaging a consulting accountant to set up the new accounting system, and the acquiring of the necessary equipment and supplies to implement his recommendations.

Chairman Reed also reported on instructions to investigate the desirability of AGU establishing an insurance plan for its members, this being especially designed to protect the member against loss of income because of illness or accident, although major medical benefits were involved. After his outline of the plans, brief discussion of this, and an informal showing of hands, indication was that a large majority was opposed to further consideration of the plan.

A motion was made and passed that:

> The Committee approve the payment of somewhat over $1000 more than alloted in the current budget for the purchasing of equipment and furniture during the current fiscal year, the purposes being to furnish two additional rooms, to acquire new typewriters, and to update office techniques.

Salaries and organization—As the work of this Committee is closely related to the problems of the budget, the president called on Chairman Sayre at this point to present his report as set forth in Appendix 3.

President Berkner noted that because of the great growth in geophysics and in the American Geophysical Union, some reorganization is essential to provide relief to the Executive Secretary in order that he may do his work effectively. It was noted that there is close collaboration between the General and the Executive Secretaries in the interpretation of day-to-day policy. It is essential that to facilitate the work of the office, two additional posts must be established—one in relationship to publications and one in relation to bookkeeping, budget, and fiscal matters.

A motion was made and passed that:

> The Officers be authorized to employ two new people to complete the top management positions under the Executive Secretary.

President Berkner especially noted that the functions of the fiscal staff member are very important in seeing to it that the NSF grant for the *JGR* and other special funds are appropriately used and charged so that the AGU is not, in fact, losing money on these operations. At the same time the persons appointed to these positions must be working personnel.

Editor Abelson noted that he has sent an accountant over to get data from the AGU books and that he has found that everything is in good shape. Items needed are readily available although the data are not assembled according to function. For example, we cannot determine readily what *JGR* is costing the membership, nor do we have our books set up in such shape that NSF auditors will accept our figures without much detailed analysis which our books might readily show with the normal course of things.

Vice President Reichelderfer thought that the hydrology problem could be worked out more readily if the Executive Secretary had more time to make the essential contacts on external affairs and not be so closely bound by activities in the office.

A motion was made and approved that:

The report of the Committee on Salaries and Organization be accepted.

A motion was made and approved to:

Engage Professor G. Chester Owens of Columbia University or some other satisfactory consulting accountant to set up a new accounting system for AGU.

In the budget adopted earlier, provision was made for such services.

At this juncture, the Executive Secretary was asked to leave for a short time to discuss matters especially relating to him. It was noted that the current retirement plan of the National Academy of Sciences is quite inadequate; plans for change are under study. The American Geophysical Union did not come under the plan until July 1, 1954, almost ten years after the incumbent Executive Secretary entered into the service of the Union.

A motion was made and passed that:

An annuity of $10,000 be purchased on behalf of any senior staff member whose service predates the initiation of the NAS retirement plan by AGU by five years or more, to be paid to the annuitant in appropriate annual units upon his retirement. The purchase payments are to be paid in appropriate annual installments during the remaining years before the 65th birthday of the staff member. It was further resolved that this be reviewed a year hence by the officers and that the Executive Committee be advised whether an additional amount of annuity appears appropriate.

Planetary Science—In the absence of Chairman Newell, Secretary Jastrow noted that the Committee had organized nine sessions for the Annual Meeting. At the time the program went to press in early March the Committee had 38 papers and by March 16 the number had increased to 68. The extensive changes in the program made it necessary to hold two sessions at one time as well as a session in conflict with the General Session of AGU. The AGU prepared a supplemental program, including abstracts, but NASA reproduced the entire series of abstracts in chronological sequence. Jastrow noted that a press conference was to be held on the afternoon of April 28. He indicated extensive interest in the Committee joining in plans for meetings on the West Coast and elsewhere in the country, feeling that the Planning Committee on Planetary Sciences was setting a good pattern of activity.

The President noted in connection with planetary sciences that nomenclature needed consideration. He felt that we should accept the word 'geophysics' as appropriate to the Moon and the planets, rather than the terms 'selenology' with respect to the Moon and 'uranology' with respect to the planets. He called attention to the editorial in a recent issue of *Science* (April 15, 1960) with respect to the broadened use of the prefix 'geo'.

At 12h 45m deliberations were suspended for one hour for lunch.

Meetings—Chairman Abelson indicated that he would undertake discussions during the Annual Meeting that would lead to a recommendation for dates of our Annual Meeting for 1961.

Joseph Kaplan, who had written a letter strongly recommending the planning of a second national meeting to be held each year on the West Coast, noted that active work in geophysics is very strong on the West Coast, especially in the fields of aeronomy and space science. He felt that a series of highly successful regional meetings had been held, appealing particularly to hydrologists, meteorologists, and oceanographers, and that these might appropriately be broadened in connection with a national meeting. He indicated that the development of the national meeting should include all areas east of the eastern boundary of Colorado and that there would be no difficulty in finding educational institutions who would be happy to act as hosts to such meetings during vacation periods. It was noted too that the Annual Meeting in Washington has grown to such size that we are having seven simultaneous sessions, often conflicting, over a period of four days, and that the siphoning off of some of this material to a good West Coast meeting is probably desirable.

L. B. Slichter noted that the Institute of Geophysics at UCLA and that Scripps would be glad to serve as hosts and that all such activity should be of tremendous service to AGU in its efforts to develop geophysics along broadest possible national lines.

Various persons from the western part of the country, including Mark Meier and C. T. Elvey, endorsed the plan.

A motion was made and carried that:

A committee be appointed to investigate the plan of the West Coast National Meeting and to bring in recommendations at the meeting of the Executive Committee meeting in the fall.

It was agreed that Joseph Kaplan be asked to serve as Chairman of this committee.

The General Secretary raised the question cited in his report concerning the matter of policy in accepting a NASA grant to aid in the work of the Committee on Planetary Sciences.

A motion was made and passed to:

Approve the acceptance of such a grant.

The Pacific Southwest Regional group met at the University of Southern California, February 5-6, 1959. Walter B. Langbein, President of the Section of Hydrology, officially represented the National Headquarters at this meeting. In his absence, Professor Kaplan reported that this was an excellent meeting, well attended, but that it failed to cover many aspects of geophysics in which members in this area are concerned and did not make full use of the talent available in the region for such a meeting. He repeated that he felt the breadth and scope would be enhanced much by making the meetings national meetings.

Membership—Chairman Earl Droessler noted that we are now receiving new members at the rate of about 50 per month and students at the rate of 25 per month, which with normal attrition, should mean a net growth of membership of about 500 per year. He pointed out that for health reasons Howard T. Orville, Chairman of the Sub-Committee for Corporation Memberships, had felt it necessary to resign. He also noted that the new classes of supporting members recently approved by the membership raise problems that will receive the attention of his Committee at an early date.

Tellers—James N. Jordan reported on the change of the Statutes by adding paragraph (g) to Article 3 (see June 1960 issue of *Transactions*, p. 335 for detailed report).

Audit—Chairman McNish had requested the Executive Secretary to communicate his report but it was not available for distribution. Action was deferred until the session of the Executive Committee on April 29 with the request that it be circulated in the interim.

In discussion it was brought out that as soon as the books are on the new basis we should plan to have an annual audit of the books by an outside auditing firm, the cost estimated not to be greater than $800. The work is now far too great to be done by a Committee. It was noted that if one can give flexibility with regard to time, the rates are somewhat less and as we need our audit only by late summer or early fall, we may well effect a substantial saving by such flexibility.

A motion was made and passed that:

We engage an outside auditing firm to make an independent audit of our accounts, taking advantage of as much flexibility as possible in timing the audit.

Finances—Vice President Reichelderfer had been appointed Chairman of a Special Committee on Finances and presented a draft report. Fred Agnich noted that our holdings include no common stock which are the best hedge against inflation but endorsed the idea that we should obtain the advice of investment bankers. L. B. Slichter noted that investment trusts should be looked into, noting further that AGU's costs are definitely tied in with the cost of living.

F. W. Riechelderfer noted that investment councilors do not suggest buying common stocks at the present as they are priced too high for the income that they provide and for possible other reasons. He noted that our Permanent Fund, which is the only fund involved in this study, amounts to only about $21,000. It was noted that the Geological Society of America invests 50% in stock, including some gilt-edge stock and some growth stock.

Chairman Reichelderfer appreciated the helpfulness of the discussion and agreed that this would make it possible for the Committee to make the necessary revisions and that a revised report would be brought in at the second session of the Executive Committee on April 29.

Dues—Earl Droessler was appointed Chairman of a Special Committee on Dues. The Committee recommended an increase from $10 to $13 per annum, noting at the same time that a minority of the Committee opposed any increase at this time. There was extensive discussion of the pro and cons of this proposition.

A motion was made to:

Accept and table the report to be taken up again after the new accounting system is in effect and the financing of the Union is better understood.

It was noted that this would hold the subscription rates at its present level for the year 1961.

Terrestrial Magnetism and Electricity Award—Fred Agnich, Chairman, referred to this as the John A. Fleming Award, which by common consent this seems to have been named. In due course a formal recommendation on the name and the scope will be made by the Committee which is now studying the matter to make recommendations whether this should be a medal or a cash award. An attempt is being made to raise $20,000. He noted that his Committee is active in collecting funds and noted further that he had raised and turned into the AGU office $1,600 in the previous two or three weeks. He appealed for aid from any who can help in the solicitation of funds or who themselves desire to make contributions. He felt that the award should not be too restrictive and should be made in fields *related* to Geomagnetism and Aeronomy. We should lay our plans to make the First Award in 1961. It was also recommended that the names of the donors

be supplied to the General Secretary and that these be especially invited to the First Award.

Geophysical and Geological Study of Continents—Chairman George Woollard presented a summary of the report set forth as Appendix 4. This report was accepted. It was agreed that the Committee is doing a splendid job and should be continued.

Cosmic Terrestrial Relationships—Chairman Vestine had no formal report but indicated that the Committee is being careful on the one hand to avoid conflict with the Section of Geomagnetism and Aeronomy and on the other hand to avoid duplication of efforts of the new Planning Committee on Planetary Sciences. The Committee had voted not to go into the field of space activities as such. He noted that he and the Vice Chairman, Walter O. Roberts, are both members of the Planetary Sciences Committee, which should be helpful in avoiding duplication.

Metric System—Floyd Hough presented the report set forth as Appendix 5.

A motion was made and approved to:

Accept the report of the Committee.

Reports of Sections

Geodesy—Charles Pierce, President, had no report but Charles A. Whitten noted that in 1961 the Section expects to be host to a symposium on geodetic satellites that the International Association of Geodesy is planning. The meeting will presumably be held in Washington.

Seismology—President Murphy noted that 76 titles had been forwarded for the use of the International Association of Seismology and Physics of the Earth's Interior. Not all of these are basic seismology, some are related to the Antarctic and to exploration seismology. Still others relate to Tectonophysics problems. He noted that our support for a laboratory of seismology approved by the Executive Committee at its meeting in mid-November 1959 is now before the Appropriations Committee of Congress. It is anticipated that the laboratory will be located in Colorado or New Mexico.

Meteorology—Secretary Jacobs noted that no late report has been received from Horace Byers regarding US participation in the Helsinki Meeting but that this seems to be extensive. He noted that the ten sessions in meteorology indicate good meetings in connection with our Annual Meeting, mentioning that a session on TIROS had been added at the last minute.

Geomagnetism and Aeronomy—President Alldredge noted that 35 papers from the United States will appear in the Geomagnetism and Aeronomy program in Helsinki and that a substantial number of United States contributions will be presented at the Aeronomy Conference to be held in Copenhagen the week preceding the opening of the Helsinki Meeting. He noted further that the program for the Annual Meeting includes 35 papers. There is some overlap with the planetary sciences sessions owing to the late inception of the planetary sessions. Considerable planning will be necessary before the meeting next year in order to avoid the repetition of this situation.

Oceanography—Secretary Pritchard indicated that there may be a report at the next session of the Executive Committee.

Volcanology, Geochemistry, and Petrology—President Nier noted the two symposia on geochemistry being planned for the Helsinki Meeting, plus 15 other papers that will fit into the program of the Association of Volcanology. Frank Schairer, Vice President of the Association of Volcanology, outlined the history of the recent effort in geochemistry, noting that P. H. Abelson was one of the co-arrangers of a general geochemistry symposium on August 25 and L. T. Aldrich one in geochronology on August 27. Both of these should help to crystallize the thought with regard to the place of geochemistry in IUGG.

Hydrology—Ralph M. Wilson, Secretary for International Participation, noted that 45 papers out of many more received, had been passed for inclusion in the Helsinki program. Included in the plans are symposia on low flows, tidal waters, and antarctic glaciology.

Tectonophysics—Secretary Gault noted that part part of the contribution cited in seismology had been obtained through the Section of Tectonophysics but that seismology was handling liaison with the International Association.

Affiliated Organizations

American Association for the Advancement of Science—At the meeting of the AAAS this coming December, it is expected that the Planning Committee on Planetary Sciences will develop one or more sessions under the guidance of Chairman Newell and Secretary Jastrow.

Unfinished and New Business—Other reports and unfinished and new business will be deferred until the second session of the Committee Meeting to be held on Friday, April 29 at about 16h 30m in the Board Room of the National Academy of Sciences.

The meeting recessed at 15h 42m.

Second Session, April 29, 1960

The second session of the Executive Committee was called to order at 16h 30m by President Berkner in the Board Room of the National Academy of Sciences—National Research Council Building, 2101 Constitution Avenue, N.W., Washington, D. C., chiefly for the purpose of attending to unfinished business held over from the first session.

Present—P. H. Abelson, L. H. Adams, L. R. Alldredge, W. W. Atwood, Jr., L. V. Berkner, Walter H. Bucher, J. J. Capello, Earl G. Droessler, C. T. Elvey, Irving Friedman, H. Richard Gault, B. F. Howell, Jr., Henry R. Joesting, J. W. Joyce,

Walter D. Lambert, H. E. Landsberg, Walter B. Langbein, Thomas F. Malone, C. C. McDonald, Mark F. Meier, L. M. Murphy, J. H. Nelson, Alfred O. C. Nier, J. A. Peoples, Jr., F. W. Reichelderfer, A. N. Sayre, A. H. Shapley, Andre C. Simonpietri, Waldo E. Smith, C. A. Whitten, R. N. Wilson, and G. P. Woollard.

International Participation—President Berkner noted that, because of the shortness of time for this meeting, it was necessary to move as rapidly as possible. It was agreed that we should defer the report on the publications of the IUGG and the discussion of candidates for officers of IUGG and its Associations until the meeting of the delegates to be held April 30, 1960.

With regard to an invitation for the Thirteenth General Assembly to be held in the United States, it was noted that the National Academy of Sciences has this under study and a decision should be reached in a relatively short time. The AGU must begin to think seriously about its responsibilities with respect to holding such a General Assembly in the United States.

It was noted that the organization of the governing body of the AGU had been under discussion for over two years and that a tentative report was published as a basis for discussion in the August 1958 issue of the *Transactions* (pp. 765–766). Revisions of this were distributed at the first session of the Executive Committee on April 25, 1960, one slight adjustment having been made to include the retiring President of AGU as a member of the Council (see Appendix 6).

A motion was made and passed that:

The report of the Committee on International Participation as published in the August 1958 issue of the *Transactions*, with amendments and changes recommended to this meeting, be formally adopted and referred to the Committee on Statutes and By Laws for the necessary modifications, and that following this the modified Statutes and By Laws be referred to the Executive Committee for a ballot by mail which, if approved, will then follow the normal course with respect to such amendments, the amendments to the Statutes requiring action by the Governing Board of the Academy and by the membership by mail ballot.

The President then noted that there are certain advantages to be gained in the form of a seasoned delegation if the AGU elections can be geared to the General Assemblies of the IUGG. Thus elections should normally take place in the fall and winter months immediately succeeding a General Assembly in order that the new officers taking office as of July 1 of the succeeding year would have two full years to plan and prepare for the next General Assembly. If the next General Assembly is to be held in the United States in the summer of 1963, it is especially important that the officers for that General Assembly take office as of July 1, 1961. The President noted that he had talked this over with various incumbent officers and that there seemed to be general agreement that this would be appropriate. Accordingly, a motion was made and passed that:

We terminate the present administration as of July 1, 1961, and that we arrange for elections during the fall months of 1960 in order that the results may be known in January 1961.

It was noted that the first part of this action affects Article 5 of the Statutes and By Laws, which requires action by the Governing Board of the Academy and the AGU membership. It was the consensus that both groups would accept this principle and that we should accordingly proceed on plans for elections this coming fall and winter while concurrently taking immediate steps to place a modified Article 5 before the Governing Board of the Academy and the AGU membership.

With regard to the matter of having the election results known in January instead of in April as hitherto, this affects the regulations established by the Executive Committee in 1946 for the holding of elections and that in order to accomplish this the schedule for elections will require that the nominations be in hand for the Union and its Sections and the Regional Committees as of July 1, 1960.

A motion was made and passed that:

Under the circumstances, recognizing the special needs of the General Assembly of the IUGG and the desirability of the election of officers at an early date to permit more effective organization of participation in the General Assembly, the Committee on Statutes and By Laws be instructed to draw up as quickly as possible a revision of Article 5 and other pertinent parts of the Statutes and By Laws as may be necessary to provide for new officers of the American Geophysical Union and its Sections and the Regional Committees to take office as of July 1, 1961, and that Article 5 be so drawn as to relate AGU elections to the normal schedule of General Assemblies of the IUGG.

It was further moved and passed that:

The regulations for elections be so adjusted that the results of the elections will be known in January instead of in April.

This means that Nominating Committees should have their reports complete and in the office of the Union, with consent of candidates, by July 1, 1960. A special meeting of the Executive Committee will be held in Helsinki for the express purpose of considering the reports of Nominating Committees in order that these may be appropriately published in the September 1960 issue of the *Transactions* (instead of the December issue as hitherto).

L. R. Alldredge offered a proposal that subsequently elections might appropriately be held a year in advance of actual assumption of office (in-

stead of three months earlier). This interval will serve as a training period for their subsequent active leadership. Thus the proposal, in effect, is that the elections following those contemplated this coming autumn will take place two years later and thereafter every three years. This will provide that these officers shall thus serve as officers-elect during the General Assembly preceding their assumption to office. This does not involve either the Statutes or the By Laws, but rather voting regulations and procedures which were established by the Executive Committee.

A motion was made and passed that:

This principle for electing officers be adopted for elections following the ones now scheduled for this coming autumn.

A motion was made and passed that:

Our time of election be adjusted so that if there is a delay or advance in the holding of a General Assembly of IUGG, the Executive Committee be authorized to adjust the election dates during such irregular periods; however, in case of international emergency involving extensive delays in General Assemblies, the triennial period would normally continue in effect.

Audit—The report of the Committee on Audit as set forth in Appendix 7 was approved.

Nominations—Chairman Walter H. Bucher advised that the Committee had met to consider a successor to F. W. Reichelderfer as Vice President and offered two candidates, namely, Thomas F. Malone and Charles A. Whitten. A motion was made and passed that:

A secret ballot be used in the election.

The result of this ballot, the Tellers announced, was the election of Thomas F. Malone as Vice President of AGU to complete the term vacated by F. W. Reichelderfer.

Finance and Investment—Chairman Reichelderfer submitted a revised draft of the report (see Appendix 8) discussed at the first session of the Executive Committee, noting concurrence by John C. Reed and John Lyman but that the fourth member (Maurice Ewing) was at sea and thus not available. He noted that the matter of investment is too serious to be entrusted to a committee. The feeling of the Committee is that the officers should seek the best advice possible for the investment of funds and that the majority of investment counsellors for the time being indicate that for the present the best plan is to put funds into secure bonds.

Looking at the longer range policy, President Berkner noted that the Academy authorizes the placing of as much as 50% of their funds in high-grade stocks. In connection with the percent to be indicated under (1) (b) of the Finance Committee report, a poll indicated that the majority recommended not more than 40% should be invested in high-grade stocks. It was moved and passed that:

The first line of item (1) in the report be made to read "The General Secretary and the Executive Secretary be authorized . . ."

Following these changes, the report was approved as published in Appendix 8.

To implement the recommendation of the report, a motion was made and passed that:

Appropriate changes be made in the Statutes and By Laws changing the name of the Audit Committee to Audit and Finance Committee.

Monograph Board—Chairman Alan H. Shapley submitted the report set forth in Appendix 9. This was accepted. President Berkner noted that if any members of the Executive Committee have comments regarding monographs, these should be forwarded promptly to the Monograph Board.

AGI Affiliation—It was noted that drastic reorganizational changes are under consideration by the American Geological Institute. This matter is under study by our representatives on the Board of Governors of the AGI, namely, Walter H. Bucher and James R. Balsley, Jr. Recommendations will be made at the next meeting of the Executive Committee.

A motion was made and passed that:

The minutes record the pleasure of the American Geophysical Union and the Executive Committee in the establishment of the new Vetlesen Prize in Earth sciences and our further pleasure in the selection of Maurice Ewing, our retiring President, as the first recipient of the prize.

Adjournment—The meeting adjourned at 17h 12m.

A. NELSON SAYRE, *General Secretary*
WALDO E. SMITH, *Executive Secretary*

Appendix 1—Report of the Russian Translation Board

PERRY BYERLY, *Chairman*

W. S. JARDETZKY, *Translation Editor*

WERNER A. BAUM
WALTER B. LANGBEIN
JOHN LYMAN
F. W. REICHELDERFER
A. E. SCHEIDEGGER
WALDO E. SMITH
VICTOR VACQUIER

Since the last meeting of the Executive Committee on November 14, 1959, the work under the guidance of the Russian Translation Board has progressed steadily. The last numbers of the *Izvestiya* series of 1958 were completed early in 1960 and distributed to the subscribers.

The Board met on January 29 in Washington, and at that time, after extensive discussion, indicated strongly the need for the rapid advance of an adequate geophysical abstracting journal. The Executive Secretary and the Chairman of the Committee on Abstracting (John Lyman, also a member of the Board) were requested to pursue this matter with the National Science Foundation, urging the expansion of the abstracting journal of the American Meteorological Society to cover the full spectrum of the hydro-atmosphere including the upper atmosphere and the Earth's environment in space, and similarly the expansion of the lithosphere phase, being prepared by the American Geological Institute. These discussions were held, and as a result it was felt that the publication of adequate abstracting journals in geophysics are a long way off.

The one being undertaken by the American Meteorological Society currently, called *Meteorological Abstracts*, covers its field on a world-wide basis, but its field needs to be greatly expanded to get the coverage to the extent outlined. The work being undertaken by the American Geological Institute is based on the North American continent only, with no particular plan to expand to a world-wide basis. Thus, we are confronted with a great need for information as to what the Russians are doing in geophysics, beyond the peephole being provided by *Izvestiya*. There are some 160 to 170 journals, we understand, on the earth sciences issued in the USSR. Complete translation is out of the question. Informative abstracts should, in the long run, be the key to satisfying the particular needs of American geophysics, and to determine what additional works should be translated, cover to cover, or by selected papers. But in the absence of such journals, additional peepholes into the Russian geophysical scene seem imperative. In the biological sciences, seven journals are being translated, and in physics, a similar number. The recommendation accordingly has been made to the Executive Committee that our coverage be extended to include *Geodesy and Cartography*, strongly endorsed by the Section of Geodesy, and *Meteorology and Hydrology*, strongly endorsed by the Section of Hydrology. This authority has been received from the Executive Committee by mail ballot, and application for a grant for the former is now in the hands of the National Science Foundation. The meeting of the Rusian Translation Board will be held on April 26 to discuss formal application for the latter. In connection with both of these publications, it is anticipated that they will be done on a contract basis, but utilizing our own translation consultant to be sure that the translations are of proper quality.

Likewise, application has been filed with the National Science Foundation for a grant to continue the *Izvestiya* project through the 1960 series. Eight numbers of 1959 have now been translated under the able guidance of Dr. W. S. Jardetzky, our Translation Editor. These are all in the hands of the compositor-printer, and the first two numbers of the 1959 series are due momentarily. The schedule calls for the completion of the 1959 series by July 1, 1960. In advance of that time we hope to have firm word from the National Science Foundation that funds will be available to proceed with the 1960 series, and even though the money may not be in hand, it is the tentative plan to proceed with the translation of the 1960 series promptly so that by the end of 1960 we will be caught up.

For 1958 and 1959, we entered into a formal contract with Mezhdunarodnaja Kniga, the official Russian publication agency, paying them $420 a year for 'translating rights' and for the supply of certain materials. Contract negotiations are still in progress for the 1960 series. Two primary points are at issue, (1) their increase from $420 to $1000, and (2) their cutting down of the material supplied us, eliminating glossy prints of the line drawings. We have expressed the thought that the payment should be about on the basis of cost, namely, about $100 a year, and that glossy black and white prints of the drawings should be supplied.

Another project in advanced stages is the translation and publication in book form of four of the *Trudy* series. This is being done on contract with Consultants Bureau. Number 37, *Collected Articles on Dynamic Meterology;* Number 38, *Isostasy and Isostatic Hypotheses;* and Number 39, *Microstructure and Macrostructure of Elastic Waves in One-Dimensional Continuing Non-Homogeneous Media*, are scheduled for comple-

tion at the end of this month. Number 40, *Investigation of the Mechanism of Earthquakes*, will be delayed until June because of the issuance of a new edition. Apparently, none beyond Number 40 has been issued by the Russians.

On April 15 the Translation Board Chairman and the Executive Secretary attended a meeting called by the National Science Foundation, which contemplated supporting an AAAS symposium relative to Chinese scientific literature. It is understood that some 60 to 70 Earth science publications are being issued by Communist China, but at this juncture it would appear that most of these are operational rather than research in their character; however, with the great upsurge of activity in seismology, geodesy, meteorology, and other aspects of geophysics on the mainland of China, it would seem to be only a matter of time until important research will be reported in their journals. This shows again the need of a world-wide abstracting journal in geophysics. The discussions on April 15 were inconclusive, and it is not known at this time whether plans for the symposium are developing or not. This presumably would be held in connection with the meeting of the American Association for the Advancement of Science in New York in December.

By way of recapitulation, it might be well to mention that the Russian translation endeavor of the American Geophysical Union started with the issuance of the 1957 series of *Izvestiya* using the translation and publication facilities of Pergamon Press. The twelfth number of that series was completed in the late spring of 1959. Only within the last week have we received documents, presumably those necessary, to effect the final settlement with Pergamon Press. Beginning with the 1958 series, we undertook the translation and publication job ourselves. W. S. Jardetzky has provided outstanding service as our Translation Editor, developing an effective panel of translators. There have been no further complaints regarding the adequacy of translations since he has taken over this work. The 1958 series got under way rather slowly; but in the last half of 1959 rapid progress was made, so that the last of the series was available shortly after the end of the year.

One of the problems involved with *Izvestiya* and which will probably be involved in the other two journals we are contemplating, is the fact that the subscription list is small, and prospects of the project being self-supporting are indeed remote. We are publishing an edition of 500, only about half of which are currently under subscription. Ideas as to how this list might be extended will be welcome.

Appendix 2—Report of the Committee on Budget for Fiscal Year 1961

JOHN C. REED, *Chairman*

L. T. ALDRICH L. O. QUAM

The following budget for the year ending June 30, 1961 is proposed by the Budget Committee. A number of *ad hoc* committees will be reporting at the Executive Committee meeting on matters that will affect the budget. Therefore, the proposed budget is subject to such modification as may be appropriate after action on the reports of the various *ad hoc* committees or after other Executive Committee actions that may affect the budget.

Regular Operations

Estimated receipts

Membership dues		
5500 members @$12[1]	$66,000	
400 student members @$4.50	1,800	
40 corporation members @$100	4,000	$ 71,800
Publications		
JGR subscriptions, 2000[2] @$25[3]	50,000	
Transactions, 1000 @combined rate of $1.00[3]		
(Rate is $4.00 for Transactions subscription only)	1,000	
Page charges and reprints, 2400 @$25	60,000	
Advertising	12,000	
NSF grant for JGR	15,000	
CIW grant for JGR	1,750	
Royalties (microcards and reprinted *Transactions*)	1,000	
Monographs	4,000	144,750

Other			
Overhead from special projects (@15%)	15,900		
National Research Council grant	400		
Interest	5,000		
Miscellaneous (includes contributions to permanent funds)	2,000	23,300	$239,850
Estimated Expenditures			
Journal of Geophysical Research			
Editorial office			
Salaries and Social Security	$ 6,800		
Honoraria	4,000		
Stationery, supplies, rent, and communications	3,000	$ 13,800	
AGU office			
Preliminary review, proofreading, processing, subscriptions, etc. (largely salaries)	15,000[4]		
Printing 12 issues (4200 pages @$30 per page)	126,000		
Reprints	7,200	148,200	
Transactions			
Preparation, proofreading, etc.	3,500		
Printing (200 pages @$30 per page) and mailing	8,000		
Reprints	400	11,900	
General Office expenses			
Rent (includes the 3 new rooms)	7,800		
Salaries[4]	29,000		
Retirement contribution	2,900		
Stationery and supplies	3,000		
Revision of bookkeeping system	2,000		
Equipment	2,000		
Postage and communications	3,500		
Promotion	2,000	52,200	
Meetings			
Regional	300		
Annual	1,800	2,100	
Miscellaneous			
Bowie medal	130		
Sections	200		
Committees	200		
Travel	2,000		
President's Fund	100	2,630	$230,830

[1] Amount based on figure used in application to NSF for grant. Committee understands that Dues Committee will recommend dues @$13.

[2] The number of subscribers is now about 1800. Committee estimates an increase of 200 in 1961.

[3] Rate justified by application to NSF.

[4] Includes provision for part time of a new Publications Assistant, not yet authorized by Executive Committee.

Non-Budget Items

Below are shown fiscal data for projects of the Union financed, or expected to be financed, by the NSF that, because of their specialized nature, are not included as regular budget items. However, 15 percent of the total of the items listed below is included in the estimate of Union receipts.

Izvestiya, 1959	$ 4,000	
Izvestiya, 1960	50,000	
Izvestiya, 1961	12,000	
Translation project	40,000	$106,000

Fifteen percent of $106,000 = $15,900

Appendix 3—Report of the Committee on AGU Salaries and Organization

A. NELSON SAYRE, *Chairman*

JOHN C. REED F. W. REICHELDERFER

The Committee, appointed to consider the matter of adequacy of AGU salaries, has considered this question. It became apparent immediately that the question of salaries was deeply involved with other questions, such as the objectives of AGU—whether they are clearly understood, the extent to which they are being realized, and the adequacy of the organizational structure needed to achieve these objectives.

We believe that the principal objectives of AGU are: (1) To promote exchange of knowledge and ideas between the diverse disciplines that comprise the field of geophysics; (2) To encourage prosecution of significant research in each of these disciplines; (3) To bring the results of such research to the attention of other Earth scientists and of the public; and (4) To act as the national committee representative of the United States in the IUGG.

These objectives can be achieved by the following means:

(1) A program of publication which would encompass the results of original investigations throughout the field of geophysics. The AGU has such a program and it is operating effectively through the publication of JGR, the Russian translations, the Monograph Series, and the Transactions.

(2) By maintaining contact with the members of AGU, especially with the leaders of the several Sections, to encourage and advise with respect to programs, cooperation between scientists, and participation in the affairs of AGU. All of these would contribute to enlarging the membership of the Union, both individual and corporation, but all possible additional means of promotion should be explored and followed through where the results seem to warrant. This would include, obviously, the arrangement and encouragement of regional meetings, as well as sponsoring the annual national meeting.

(3) Maintaining contact with the various committees appointed by the President, to insure so far as posible the prompt execution of committee assignments and the orderly progression of the achievement of AGU objectives.

(4) Securing adequate financial resources to support the legitimate activities of the AGU through collection of dues, collection of page charges for the *Journal*, obtaining grants for specific purposes, and promoting the campaign to secure greatly increased revenue from advertising in the *Journal*.

(5) Effective management of the financial affairs of AGU and adequate supervision of the office force.

Some essential activities of AGU may have been omitted, but it is believed that the list covers most of the important ones.

The responsibilities considered above must devolve primarily on the executive office of the AGU. However, to carry them out, the executive office has a full-time staff of only one professional and three secretarial employees and the part-time services of seven employees. This does not include the editors of the JGR or their assistants, the translation editors, or the Monograph editors. Considering the complexity of the task, the executive office seems woefully understaffed both as to quantity and quality.

From the standpoint of organization, the office appears also to be rather weak. The Executive Secretary participates, at least to some extent, in all the activities of the office except the keeping of accounts. His salary is $13,500, which is probably on the low side for similar positions in other organizations. The next highest salary paid is only $6,000. This means that the Executive Secretary has no understudy who could take over, at least temporarily, in case anything happened to the Executive Secretary such as an accident or a protracted illness, and the AGU would be in serious difficulty until a replacement could be found. However, perhaps more important than the possibility of a catastrophic situation is the need for a division of responsibility in the executive office so that a senior member of the executive staff could begin to function in some of the activities that are now neglected or carried on under severe handicaps because of the pressure of other duties. There are not enough hours in the day for the Executive Secretary to perform all of the duties that he has assumed or that have been thrust upon him, and we shall not be properly staffed until these gaps are filled.

No reflection on the performance and capabilities of individuals in the office is intended or implied in this report. In fact, Waldo Smith and his staff have carried on remarkably well under severe handicaps brought about by rapid expansion in the programs and activities of the Union. However, it seems clear to your committee that if the Union is expecting to keep abreast of the greatly increased responsibilities which it has assumed immediate expansion of the organization of the executive office is essential. The fiscal and management responsibilities of the office are now efficiently handled, but they are of sufficient magnitude to require the full-time attention of one person, along with the necessary clerical assistance. This function should be recognized by the designation of an Office Manager, who would receive

the salary and recognition that is merited by the responsibility assumed. These responsibilities are now adequately handled by a member of the existing staff, although she does not carry the title or the salary which the position warrants. Likewise, the publication program requires the attention of a competent scientist of considerable capacity for administration, who would be able to act as Assistant Executive Secretary in case of need. Filling this position would require the selection and appointment of an additional full-time employee at a salary in the neighborhood of $8000.

The committee recommends that no action relating to salaries be taken at present beyond authorization for the designation of an office manager and appointment of a publications officer, but in view of the inadequate retirement provisions for the Executive Secretary, steps be taken to provide an annuity of $10,000 payable at age 65, the premiums therefore to be pro-rated from this date. The committee also recommends that a thorough study of the organization of the executive office be made by an *ad hoc* committee of high-level people who have demonstrated organizational capacity and who are willing to spend the time necesary to comprehend the needs of the organization.

Appendix 4—Report of the Special Committee for the Geological and Geophysical Study of the Continents

GEORGE P. WOOLLARD, *Chairman*

W. E. BONINI
R. A. GEYER
SIGMUND HAMMER
J. C. HARRISON
P. M. HURLEY
M. J. S. INNES
H. R. JOESTING
GORDON G. LILL
PAUL L. LYONS
J. A. PEOPLES, JR.
FRANK PRESS
DONALD A. RICE
NELSON C. STEENLAND
J. TUZO WILSON
J. LAMAR WORZEL

At a meeting of the committee held in Washington at the time of the 1959 meetings of the Union considerable discussion was devoted to projects now in progress relating to the geological and geophysical study of the continents and what the committee could do that would implement these studies. The following appeared to be worth while objectives.

(1) The sponsorship of crustal studies: (a) by cooperative seismic studies of crustal structure between university, governmental, private and industrial groups, (b) by interdisciplinary geophysical studies of both the crust and surficial geologic features, and (c) by the further development of geophysical field and analytical studies in the various universities not now engaged in such studies through the loan of equipment, incorporation of students on programs at universities having going programs, other help such as making available IBM programs and facilities.

(2) Completion of the Bouguer and free-air anomaly gravity maps of the United States.

(3) Cooperation with the American Association of Petroleum Geologists committees on the new tectonic and basement maps of the United States. The Chairman is happy to report that substantial progress was achieved in all three programs.

Through the loan of gravimetric and magnetic instruments from the University of Wisconsin a field program was initiated at Michigan State University and the program at the Virginia Polytechnic Institute expanded. Likewise, the Antarctic program of the Falkland Island Dependencies was broadened by the inclusion of gravity measurements through the loan of a gravimeter made available to Lamont Geological Observatory for use in making ties to land gravity bases for their marine gravimetric program. Instruments were also loaned to the U. S. Air Force for the standardization of new gravimetric instruments they had just purchased. Seismic equipment was loaned by the Department of Terrestrial Magnetism to both the University of Wisconsin and Princeton University, and problems of recording in crustal work discussed at various conferences in order to improve instrument design and capabilities. The University of Wisconsin built copies of their amplifiers for the Princeton University seismic equipment so that comparable results could be obtained.

In connection with the gravimetric map of the United States being prepared by the Committee, close cooperation has been obtained from not only the U. S. Coast and Geodetic Survey and the U. S. Geological Survey, Geophysics Branch, but from most of the major oil companies and all of the university groups having gravity programs. The final map should be ready to go to the U. S. Geological Survey for printing on a scale of 1: 2,500,000 sometime in the Fall.

During the summer the University of Wisconsin and the Department of Terrestrial Magnetism of the Carnegie Institution joined forces to undertake simultaneous seismic measurements both along and across the tectonic grain of the country in the Rocky Mountain region. Princeton University also participated in these measurements, as did a contract seismic crew from Geophysical

Service Incorporated. The latter recorded alongside one of the University of Wisconsin crews in order to determine the signal-to-noise ratio, and other characteristics of industrial seismic equipment relative to that which had been developed for crustal studies by the University of Wisconsin and Department of Terrestrial Magnetism. These tests were disappointing in that the industrial equipment did not give satisfactory records at ranges beyond 225 km. The Wisconsin-D.I.M. equipment, however, did yield satisfactory records out to the maximum range of recording, 410 km. The measurements along strike were reversed, those across strike were open-ended.

The results obtained were both gratifying and of interest in that they showed (a) that phase correlations could be carried satisfactorily over great distances with a limited number of recording crews (six) using multiple shots at a single point, (b) satisfactory records could be obtained from explosive charges not exceeding 1000 lb at distances of 400 km, (c) that the crust in the Montana-Idaho area has multiple velocity layering, defined by late arrivals at short ranges and first arrivals at extreme ranges, and (d) that the crust in front of the Rocky Mountains in Montana, although of similar structure, is actually somewhat thicker than that in the Rocky Mountains.

At first glance this appears to be an anomalous situation, but it is in agreement with the results predicted from the combined Bouguer and isostatic gravity anomaly relationships. The difference in surface elevation under isostatic theory for a crust of constant density suggests that the crust should be thicker beneath the mountains. The seismic velocity values and isostatic anomaly values, however, indicate that the crust in front of the Rocky Mountains has a higher mean density than that in the mountains, and as a consequence there is less free board and a lower surface elevation in association with a greater depth to the Mohorvicic discontinuity, in accordance with Archimedes' principle for a floating body.

Also of interest from the standpoint of crustal structure is the analysis made at the University of Wisconsin of regional magnetic anomalies. It appears likely that these are related in some areas to the configuration of the basaltic layer. In Arkansas the computed magnetic depths agree to 0.5km with the seismic value observed for the intermediate layer. Other areas are now being studied.

Magnetics have also been utilized by the University of Wisconsin to study the crystalline rock surface of the Atlantic Coastal Plain in connection with the basement map project upon which the committee is working with the American Association of Petroleum Geologists. This study shows five major basins in the Georgia-Florida area lying beneath the Cretaceous sediments, with depths in excess of 10,000 feet.

Through the radioactive dating programs, particularly those at MIT, the University of Minnesota, the Department of Terrestrial Magnetism of the Carnegie Institution, the Lamont Geological Observatory, and the University of Toronto, it appears it will soon be possible to get together a map for most of North America and much of the rest of the world relating the ages of the various tectonic events.

In Antarctica it is now quite clear that the Andean Mt.—Scotian Arc system seen entering Antarctica through the Palmer peninsula extends inland as a narrow ridge separating the Ross Sea and Wedell Sea embayments to the vicinity of the Horlick Mts. The ridge is not continuous, and is broken by several narrow valleys. The wide and deep bedrock trough observed in the vicinity of Byrd Station, and which extends more than 5000 feet below sea level, lies to the west of the ridge and appears to connect the Ross Sea and Belinghausen Sea. There is little doubt that western Antarctica would still remain mostly below sea level if all the ice were to melt and the area to rise isostatically, and that only eastern Antarctica would constitute a true continental mass.

It is gratifying to note that several Antarctic geologic programs have been submitted to the National Science Foundation for consideration, and that the Office of Naval Research has given the University of Wisconsin support for a gravity and magnetic reconnaissance study of the Arctic offshore area between Pt. Barrow and Barter Island, Alaska, as a preliminary study for seismic crustal work to be carried out jointly by the University of Wisconsin and the Lamont Geological Observatory next year.

It is also noted with pleasure the increased interest in crustal seismology and earth science by industrial groups. Geophysical Service, Inc., for example, has established an Earth Science Division, and a group of companies under the auspices of the Tulsa Geological Society carried out a reflection measurement of crustal structure in the vicinity of Tulsa during the past year. A depth of 13 km was found for the Conrad discontinuity and 38 to 43 km for the Mohorovicic discontinuity, depending upon the velocity value used.

Appendix 5—Third Progress Report of the Committee for the Study of the Metric System in the United States

FLOYD W. HOUGH, *Chairman*

CARL I. ASLAKSON
FINN E. BRONNER
JOHN G. FERRIS
HELMUT E. LANDSBERG
G. MEDINA
JOHN A. O'KEEFE
MILTON O. SCHMIDT
LANSING G. SIMMONS
GEORGE W. WHITMORE
L. V. JUDSON, *Consultant*

As anticipated in Progress Report 2 of November 14, 1959, this Committee has continued in a more or less "standby" status pending action on the Congressional bills, one in the Senate and one in the House (S 2420 and HR 7401) and the Concurrent Resolution (H. Con. Res. 364). Both bills call for thorough studies by the Department of Commerce of the advantages and disadvantages of the Metric System in the United States. The Concurrent Resolution would place the Congress on record as favoring the Metric System (see report pp. 371 and 372, *Trans.*, vol. 40, 1959).

All three proposals were referred to appropriate committees of the Congress and hearings are now pending, with no dates for such hearings having yet been set.

The Special Committee feels that it is not justified in spending AGU allotted funds in further study of the problem except for minor correspondence, until we know if Congress is going to approve either the Senate or House bill. Such a study by the Department of Commerce would no doubt be far more comprehensive than we could undertake and even our minor effort would tend to be duplicative.

The Committee has communicated with the Congressional sponsors of the three bills pending, and with the Director of the Bureau of Standards who would conduct the study under the proposed bills. Replies have been received in all cases, expressing appreciation of the Committee's offer of assistance and use of material in its files. No lobbying will be done by the Committee, as such would be contrary to AGU policy. If called on, members of the Committee will assist at the hearings.

No meeting of the Metric Committee has been held since the last AGU Executive Meeting in November 1959. Considerable correspondence has been carried on with interested parties in this country and with some abroad. Several hundred reprints of the Committee Progress Report as published in the September and December 1959 AGU *Transactions*, including the tabulation analysis of 1080 completed questionnaires, were forwarded on request. A present total of more than 1200 completed questionnaires have been received from scientific and engineering personnel of which 90% favor a changeover to the Metric System within a long transition period of 22 years.

The expenditures of the Committee have approximated $50 of the $250 allotted for the fiscal year 1960. The question arises as to whether the Special Committee should be continued. If it is continued, the balance remaining from 1960 fiscal year allotment should be made available for committee expenses in fiscal year 1961.

Appendix 6—Report of the Committee on International Participation: Proposed Council of the American Geophysical Union

J. W. JOYCE, *Chairman*

LEASON H. ADAMS
WALTER H. BUCHER
MAURICE EWING
F. W. REICHELDERFER
WALTER V. ROBERTS
CHARLES A. WHITTEN
LLOYD V. BERKNER
A. NELSON SAYRE
WALDO E. SMITH
ex officio

Since January 1958, when the initial proposal for a modified Executive Committee, to be called the Council of the American Geophysical Union and to act as the U. S. National Committee to the IUGG, was made, several modifications of this scheme have occurred based on further discussions of the problem. The original proposal was published in TRANSACTIONS OF THE AGU, Volume 39, No. 4, August 1958, pages 765–6.

One objection to the revised Council concerned the number of non-AGU-elected members who would sit on this body. The total size of the Council was also questioned.

In answering the first question, it was pointed

out that as far as its function as the U. S. National Committee to the IUGG was concerned, the Council must of necessity adequately represent *all* elements of U. S. geodesy and geophysics, and that as a matter of fact, it would be highly probable that practically all persons selected will be members of the AGU. As a further assurance that AGU domestic and financial policies would not be set by non-AGU members, it was proposed that when the Council voted on such matters, only those members of the Council who were also members of the AGU would vote.

In answering the second objection regarding the size of the Council, the proposal now presented reduces the total number by eliminating various ex-officio members that had been suggested in the January 1958 proposal.

The proposal now presented for consideration calls for the following make-up of the Council of the American Geophysical Union:

—President, Vice President, General Secretary, Retiring President, and Secretary for International Affairs of the Union	5
—the President or his designated representative of each Section of the Union	8
—one member nominated by each of the following Government agencies: Department of Defense; Department of the Interior, Department of Commerce, National Science Foundation	4
—the Foreign Secretary of the NAS-NRC	1
—the Chairman of the Section of Geophysics of the NAS	1
—the Chairman of the Division of Earth Sciences of the NRC	1
—3 members at large nominated by the Section on Geophysics of the NAS	3
—Officers of the IUGG who are U. S. citizens and resident in the U. S.	?
	23 plus IUGG officers

As in the earlier proposal the names of all of the above persons would be nominated to the National Academy of Sciences, and their formal appointment on the Council would be made by the President of the Academy. This is at present common practice in a number of other U. S. National Committees for ICSU unions.

Also, as in the previous proposal, an Executive Committee would be selected from the Council to consist of the President, Vice President, Secretary General, and Secretary of International Affairs of the AGU, and five members of the Council designated from among the voting members of the Council by the National Academy of Sciences upon the recommendation of the Council. This Executive Committee would handle the affairs of the Union in accordance with policy decisions of the full Council. This Committee could be convened quickly at times between annual or semi-annual meetings of the Council.

The same conditions on voting, domestic policies and fiscal matters, referred to above, would also apply.

Appendix 7—Report of the Committee on Audit for the Fiscal Year Ending June 30, 1959

A. G. McNish, *Chairman*

A. P. Crary E. B. Roberts

Reference is made to the preliminary report of the Audit Committee made last fall (see *Trans.*, March 1960, p. 67). The Committee feels that it has discharged its responsibility and can assure the President and Executive Committee of the Union that the accounts are in good order.

The Committee understands that its recommendation that a study be made of the bookkeeping system of the Union to modernize it in accord with present operations has been followed. Therefore, the Committee on Audit recommends to the President and the Executive Committee approval of the books as kept by the Executive Secretary.

Permit us to repeat that our preliminary report was in no way a reflection on the thoroughness and accuracy with which the records have been kept, but only an expression of opinion in recognition of the growing activities of our Union.

Operating Statement

(Fiscal year ending June 30, 1959)

Receipts			
NAS-NRC grant for publication			$ 400.00
Income			
Dues, 1956 and earlier	$ 127.00		
1957	267.00		
1958	3,145.49		
1959	47,936.42		
1960 et seq.	287.40		
Corporation memberships	3,000.00	$54,763.31	
Sales of publications			
Journal of Geophysical Research	$22,922.31		
Transactions	5,794.07		
Reprints, *JGR*	5,100.00		
Reprints, *Transactions*	4,115.32		
Reprints, Geophysical Monogr. No. 2	852.00		
Geophysical Monograph No. 1	902.10		
Geophysical Monograph No. 2	6,573.70		
Geophysical Monograph No. 3	574.74		
Miscellaneous	65.72	46,899.96	101,663.27
Contributions to Permanent Fund			1,898.50
Interest on Permanent Funds			616.16
Interest on T. M. and E. Award Fund			64.38
Interest on deposits with Enterprise, Home, and Interstate Building Associations			487.01
Interest on deposit with Riggs National Bank			656.29
Interest on U. S. Treasury Notes ($875.00) less $386.74 accumulated interest paid by AGU at date of purchase)			488.26
Interest on U. S. Savings Bonds (maturity value $2,500 less $1,850, cost price in 1948)			650.00
Advertising receipts			6,900.33
Sale of equipment (1 fan)			25.00
Microcard royalties			68.27
Reprint royalties			1,135.81
IGY Bulletins			9,351.01[a]
Russian Translation Projects			
NSF suppl. grant, *Izv.*, Geophysics Series, 1957		$16,036.00	
Subscriptions, *Izv.*, Geophysics Series, 1957		87.50	
NSF grant, *Izv.*, Geophysics Series, 1958		44,835.00	
Subscriptions, *Izv.*, Geophysics Series, 1958		122.50	61,081.00[b]
NSF grant, Conference on Physics of Precipitation (and Monograph 5)			25,000.00[b]
NSF grant, Conference on Contemporary Geodesy (and Monograph 4)			6,800.00[b]
NSF grant, International Association of Geodesy Conference			4,500.00[b]
NSF grant, partial support of *JGR* and *Transactions*			75,000.00
Conference on Atmospheric Chemistry (and Monograph 3) (NSF through NAS)			1,034.65[b]
Miscellaneous			258.98*
Total receipts			$298,078.92

* Includes $75.00 issued as a check June 30, 1958, for deposit in the Prudential Building Association account, but which was not deposited until July 2, 1958, and thus did not appear in the assets as of June 30, 1958.

Disbursements		
Journal of Geophysical Research		
Preliminary	$ 1,583.25	
Proofreading	1,133.85	
Printing and mailing	24,709.19	
Administrative	782.97	

Processing subscriptions, etc.	2,697.81	
Promotion	4,950.36	
Editors' accounts		
Salaries (including honoraria to editors)	6,774.31	
Stationery and supplies, etc.	1,685.05	
Advertising expense	71.05	$ 44,387.84
Transactions		
Preparation of copy and proofreading	$ 4,256.66	
Printing & mailing (3 bimonthly numbers, 1 quarterly)	20,776.53	
Honoraria to editors	750.00	25,783.19
Geophysical Monographs		
No. 1	$ 5.02	
No. 2	5,687.01	5,692.03
Reprints		
Transactions	$ 1,656.92	
Journal of Geophysical Research	1,191.54	
Geophysical Monograph No. 2	398.44	3,246.90
General expenditures (office of the Union)		
Salaries (including Federal social security)	$19,950.83	
Equipment	1,254.79	
Stationery and supplies	2,209.66	
Rent	4,237.44	
Postage and communication	2,677.89	30,330.61
Retirement contribution		1,062.56
Committees and Sections		150.37
Expenses, meetings		
Annual	$ 1,810.73	
Regional	155.70	1,966.43
Russian Translation Projects		
Geophysical Abstracts, direct costs	$ 840.00[a]	
Refunded to NSF, closing Geophysics Abstracts project	12,788.00	
Izvestiya, Geophysics Series, 1957, direct costs	18,837.84[d]	
Izvestiya, Geophysics Series, 1958, direct costs	8,439.75	
Trudy, direct costs	9.87	40,915.46[b]
Conference on Physics of Precipitation (and Monogr. 5), direct costs		11,173.02[b]
Conference on Contemporary Geodesy (and Monograph 4), direct costs		1,716.55[b]
Conference of International Association of Geodesy		4,500.00[b]
Conference on Atmospheric Chemistry (and Monogr. 3)(NSF through NAS)		1,385.35[b]
Travel		233.24
IGY Bulletins		9,325.33[a]
Bowie Medal		102.23
Miscellaneous		89.23
Total disbursements		$182,060.34

[a] Receipts and disbursements cancel over an interval of two or three years.
[b] Non-budget items.
[c] The amount of $4,127.00 of the $10,168.86 in the 1958 report was on the Geophysical Abstracts project. This project is closed.
[d] The amount of $6,041.86 of the $10,168.86 in the 1958 report was on *Izvestiya*, Geophysics Series, 1957.

Excess of receipts over disbursements

Receipts			$298,078.92
Disbursements			182,060.34
			$116,018.58[a]
Adjustments for non-budget items			
Less (Receipts)			
Russian Translation Projects	$61,081.00		
Conference on Physics of Precipitation (and Monograph 5)	25,000.00		
Conference on Contemporary Geodesy (and Monograph 4)	6,800.00		
Internat. Assn. of Geodesy Conference	4,500.00		
Conference on Atmospheric Chemistry (and Monograph 3)	1,034.65	$98,415.65	
Plus (Disbursements)			
Russian Translation Projects	$40,915.46		
Conference on Physics of Precipitation (and Monograph 5)	11,173.02		
Conference on Contemporary Geodesy (and Monograph 4)	1,716.55		
Internat. Assn. of Geodesy Conference	4,500.00		
Conference on Atmospheric Chemistry (and Monograph 3)	1,385.35	59,690.38	
Adjustment to excess of receipts over disbursements			38,725.27
Excess of receipts over disbursements, budget items			$ 77,293.31

[a] A considerable part of this amount is derived from the fact that the first six numbers of the *Journal of Geophysical Research* totaled only 695 pages compared with 1200 pages estimated in the grant application to the National Science Foundation on which AGU received $75,000 chiefly for the *calendar* year 1959 in support of the publication of the *JGR* and the *Transactions*, this being the first payment of a total grant to the extent of $146,000 over a five-year period. The *Journal* will be much larger in the last half of the calendar year 1959.

Statement of Assets and Liabilities as of June 30, 1959 (see pp. 1194–1196 of Dec. 1958 *Transactions* for statement of assets and liabilities as of June 30, 1958)

Assets			
Cash Reserve			
On deposit in Riggs National Bank	$54,530.38[a]		
On deposit in Prudential Bldg. Assn.	500.00		
On deposit in Interstate Bldg. Assn.	10,096.31		
On deposit in Enterprise Federal Savings and Loan Assn.	10,000.00		
On deposit in Eastern Bldg. and Loan Assn.	10,000.00		
On deposit in Home Bldg. Assn.	10,000.00		
U. S. Treasury Notes	49,937.50		
U. S. Treasury Bills	19,692.62	$164,756.81	
Permanent Fund			
Series F bonds purchased prior to July 1, 1948 (maturity value $700), at cost	$ 518.00		
On deposit in Northwestern Federal Savings and Loan Assn. as of July 1, 1959	9,999.04		
On deposit in Prudential Bldg. Assn. as of July 1, 1959.	8,253.28	18,770.32	
Emergency Fund			
On deposit in Prudential Bldg. Assn. as of July 1, 1959		1,000.00	
T. M. and E. Award Fund			
On deposit in Liberty Bldg. Assn. as of July 1, 1959		1,399.58	$185,926.71

Bills Receivable			
Dues			
1959 only	$ 3,794.50		
1958 and 1959	2,749.00	$ 6,543.50	
Publications			
Transactions and *JGR*	$ 277.50		
Reprints	4,192.50		
Miscellaneous	30.50		
Geophysical Monograph No. 1	171.89		
Geophysical Monograph No. 2	408.52		
Geophysical Monograph No. 3	1,065.26		
Subscriptions	1,236.00		
Advertising	91.66		
IGY Bulletins	2,853.59	10,327.42	
Conference on Atmospheric Chemistry (and Monogr. 3)		231.65	
Interest Receivable from Home, Enterprise, and Eastern Bldg. Assns.		366.70	17,469.27
			$203,395.98
Liabilities			
Bills Payable and advance payments			
Dues in advance (1960 et seq.)	$ 317.40		
Subscriptions in advance (1960 et seq.)	416.80		
IGY Bulletin	805.63		
Transactions	3,192.54		
Monograph No. 3	2,736.87		
Misc. (mainly credits on overpayments)	152.12	$ 7,621.36	
Commitments			
Russian Translation Projects			
Izv., Geophysics Series, 1957	$10,361.64		
Izv., Geophysics Series, 1958	35,569.43		
Conference on Physics of Precipitation (and Monograph 5)	12,285.55		
Conference on Contemporary Geodesy (and Monograph 4)	4,825.97	63,042.59	$ 70,663.95
Surplus (Capital Account)			132,732.03
			$203,395.98
* Riggs National Bank statement of June 30, 1959			$ 64,499.79
Less checks outstanding			9,969.41
			$ 54,530.38

SUMMARY

Liquid assets as of June 30, 1958, as published on page 1196 of the December 1958 issue of the *Transactions*	$ 69,908.13
Excess of receipts over disbursements, July 1, 1958 to June 30, 1959, as shown in this statement	116,018.58
Liquid assets as of June 30, 1959, as per this statement	$185,926.71

Appendix 8—Report of the Committee of Finance and Investment, on Investment Problems of the American Geophysical Union

F. W. Reichelderfer, *Chairman*

Maurice Ewing John Lyman

John C. Reed

In its meeting November 14, 1959, the Executive Committee adopted a motion providing that: "A Finance Committee be established to study the investment problems of the American Geophysical Union" (*Transactions*, AGU, March 1960, Vol. 41, No. 1, p. 64). During discussion before adoption of the motion a question was raised as to whether anything is being done to invest the permanent funds of the AGU in stocks or other equities that would "hedge" against loss in value of capital as result of future inflation. The life membership payments of individuals were mentioned as especially vulnerable in this regard. The General Secretary pointed out that the permanent funds of the Union in October 1959 amounted to about $20,000. The greater amounts shown in the table of assets are short-term grants that must be kept in forms available for cash on relatively short notice, that is, in savings accounts, short-term Treasury notes or similar securities.

During the past five months the Finance Committee has obtained information on investment practices of several scientific and educational institutions, among them the National Academy of Sciences, the Geological Society of America, the Massachusetts Institute of Technology, and the American Meteorological Society. Also, numerous sources of investment counsel have been consulted including several reputable investment bankers and better known stock brokers, and a few of the standard investment advisory services.

There appears to be common agreement among investment counsellors that over the long term further inflation is to be expected and therefore investment in sound growth stocks or other "safe" equities is necessary to protect capital values. However, many point out that prices of gilt-edge stocks are high at the present time and brokers advise caution for the time being. They remind us that although stocks and mutual or trust funds have on the whole risen greatly in value during the past decade or two, there is no assurance that they will continue to rise. In fact, they might sell off considerably before another long pull rise sets in. A few investment advisors suggest that funds be kept in high grade bonds or other fixed income securities which now offer relatively high yields compared with the yields on good stocks. Consideration should be given also to convertible bonds and certain preferred stocks with conversion privileges which offer some opportunity to share in growth of corporations and thus "hedge" against inflation as well as give greater stability in market price than is usually the case with common stocks. There are new political and international factors in the world today which tend to add to uncertainties in the investment outlook. Wide divergence in advice is therefore to be expected and this is what was found in our review of investment recommendations.

Majority opinion at the present time appears to favor the view that the permanent funds of AGU as well as the temporary funds should be kept for the time being in high grade bonds, building and loan deposits or similar investments such as those listed in the assets shown in the March 1960 *Transactions*, but at the same time the officers of the Union should be authorized to keep in touch with sound investment counsel with the view to converting a reasonable portion of the permanent funds into growth stocks or other suitable equities when in their judgment, after consultation with investment counsellors, it would be advantageous for the Union to do so.

There are many recognized sources of investment counsel. However, with a permanent fund of less than $50,000 it may not be profitable for the Union to employ an individual investment counsellor as some of the larger organizations responsible for institutional funds do. For the present the Committee believes that investment advice should be obtained from reputable investment bankers who provide such service to bank customers without charge. An important feature of good investment practice is that there should be more or less continuous "supervision" of investments. Accordingly, it would be necessary periodically to review with the aid of sound investment advice, the status and prospects of securities in the investment portfolio. An annual report to the Executive Committee on action taken to obtain investment counsel and on the status of securities and the changes during the year should be transmitted to the Auditing Committee for review and comments and then forwarded to the Executive Committee for final review.

After considering the information and recommendations that have been brought to its attention, your Finance Committee recommends that:

(1) the General Secretary and the Executive Secretary be authorized to invest the funds of the Union in securities which in their judgment, after consultation with investment counsellors, will best serve the interests of the Union, provided that

(a) short-term funds not required for immediate cash transactions be invested in insured savings accounts, short-term Treasury notes or U. S. bonds, federally-insured building and loan associa-

tion deposits or equivalent stable and readily marketable forms, and

(b) permanent funds be invested in high-grade longer term securities of which not more than 40% initially may be placed in good "growth" stocks or other high-grade equities when in the judgment of reputable investment counsel the securities market is favorable for stock investments, except that each year at least 60% of that year's receipts for life memberships should be invested in such equities. (It is desirable to define "permanent funds" more clearly and to provide for transfer of amounts to the "permanent funds" category when appropriate.)

(2) the General Secretary will report annually to the Executive Committee the action taken during the year to obtain and use investment counsel and the status and changes in the investment portfolio of the Union, and

(3) the Auditing Committee will review and comment on the adequacy of the action contained in the report on the investment portfolio of the Union.

Appendix 9—Report of the Geophysical Monograph Board

A. H. Shapley, *Chairman*

P. H. Abelson
Herbert Friedman
J. A. Jacobs
Walter B. Langbein
Homer E. Newell, Jr.
Frank Press
Donald W. Pritchard
B. Rossi
Harry Wexler
Charles A. Whitten

There have been many suggestions for volumes in the Geophysical Monograph Series, but thus far the Board has not taken any specific decisions. The most significant general suggestion has been that the Monograph Series be made available for extenso reports on the U. S. Antarctic science programs, in particular for the IGY period. There have been many favorable comments on this suggestion, although there is a body of opinion that these works might better be in larger format and therefore might constitute a parallel series to the main Monograph Series.

(A) Recommended by AGU Glaciological Committee, Mark Meier, Chairman: (1) antarctic traverses (about seven authors from four institutions), (2) station and traverse glaciology (about four authors), (3) antarctic deep drilling, and (4) a volume on glaciers: the present state of the science of glaciology (John Mye).

(B) Proposed by D. J. Masson, Rand Corporation: (1) aerodynamics of the upper atmosphere (a 1959 Rand symposium, extant as a Rand report).

(C) Proposed by George P. Woollard: (1) Discussions of gravity data used in world maps.

(D) Proposed by L. V. Berkner: (1) Symposia at forthcoming Tenth Pacific Science Congress, 1961.

(E) Others less formally.

The Chairman of the Board would intend to arrange for formal action by the Board on one or more of these proposals in the near future.

Questions continue to be raised regarding publication of symposium papers in the Monograph Series, and the Chairman has had further discussions with the Editors of the *JGR*. It is the Chairman's view that in general the *JGR* should have first refusal of collected symposium papers either in the *JGR* itself or in a supplement. Volumes in the Monograph Series would seem appropriate principally in cases where timeliness of appearance and timeliness of distribution are not prime factors.

SPECIAL ANNOUNCEMENTS

List of Official Nominees for Officers of the Union, of the Sections, and of Two Of the Regional Committees for the Triennium July 1, 1961 to June 30, 1964

Union or Section	President	Vice president	Secretary[a]
Union	Thomas F. Malone	Charles A. Whitten George P. Woollard	A. Nelson Sayre
Geodesy	Floyd W. Hough	Charles A. Whitten	Buford K. Meade
Seismology	James A. Peoples, Jr.	Jack E. Oliver	Ben F. Howell, Jr.
Meteorology	Francois N. Frenkiel Walter Orr Roberts	Henry G. Houghton William W. Kellogg	Woodrow C. Jacobs
Geomagnetism and Aeronomy	C. T. Elvey	E. H. Vestine	J. H. Nelson
Oceanography	Clifford A. Barnes Donald W. Pritchard	Robert S. Arthur Dayton E. Carritt	Charles C. Bates Arthur E. Maxwell
Volcanology, Geochemistry, and Petrology	Hatten S. Yoder, Jr.	Edward D. Goldberg	David R. Wones
Hydrology	William C. Ackermann	Alfred J. Cooper David K. Todd	Ralph N. Wilson
Technophysics[b]	Louis B. Slichter	David T. Griggs	Iris Borg

[a] For General Secretary in the case of the Union.

[b] Two members of the Executive Committee of the Section are to be elected also. The nominees are George A. Thompson and Patrick M. Hurley.

NOMINEES FOR REGIONAL COMMITTEES (nine to be elected)

Pacific Southwest Regional Committee (Arizona, California, and Nevada)
Hydrology: Arthur F. Pillsbury, Joseph F. Poland, David K. Todd
Oceanography: Charles S. Cox, Jacob S. Wickham
Meteorology: W. D. Duthie, Robert E. Holzer, Morris Neiburger
Geomagnetism and Aeronomy: E. H. Vestine

Pacific Northwest Regional Committee (Idaho, Montana, Oregon, Washington, and Wyoming)
Geodesy: Fred Natella
Seismology and Tectonophysics: Robert DeLuccia
Meteorology (two to be elected): Robert Beaumont, Lenard Bissell, Fred Decker
Geomagnetism and Aeronomy, and Volcanology, Geochemistry, and Petrology: Keith E. Anderson
Oceanography: Robert Paquette
Hydrology (three to be elected): Charles L. Barker, Hollis Orem, Robert Russell, Meredith Thoms

North Central Regional Committee (Minnesota, Iowa, Missouri, North Dakota, South Dakota) Nominations pending

Explanatory note—In accordance with the Statutes and By Laws as amended, elections by mail ballot are to be held in late 1960. The Committees on Nominations for the Union and the Sections were appointed as follows, with the first-named as Chairman: *Union*, Walter H. Bucher, J. F. Schairer, and E. H. Vestine; *Geodesy*, Milton O. Schmidt, Albert J Hoskinson, Gunnar

Leifson, and Julius L. Speert; *Seismology,* Hugo Benioff, Ross R. Heinrich, and Carl F. Romney; *Meteorology,* Earl Droessler, Werner A. Baum, and Jack C. Thompson; *Geomagnetism and Aeronomy,* Joseph Kaplan, J. W. Joyce, and Victor Vacquier; *Oceanography,* Alfred C. Redfield, John Lyman, and Warren S. Wooster; *Volcanology, Geochemistry, and Petrology,* J. F. Schairer, L. Thomas Aldrich, Irving Friedman, and Samuel S. Goldich; *Hydrology,* Louis M. Glymph, Jr., with the assistance of a commitee of 25-30 members; *Tectonophysics,* Harry Hughes, B. F. Howell, and J. B. Thompson; *Pacific Southwest Region,* Arthur F. Pillsbury, and Jacob B. Wickham; *Pacific Northwest Region,* Milton S. Sachs, and Albert Moore.

The Executive Committee of the Union has established procedures for nomination and election of officers of the Union, as published in the December 1946 issue of the *Transactions,* page 910. These are adjusted from time to time, but in principle are still effective; the up-to-date version of these is as follows: (1) Nominations shall be initiated by a small Nominating Committee consisting of three or five members, appointed by the President. (2) The Committee on Nominations shall use its discretion as to the number of nominees it may submit for the office. (3) Such nominations shall then be submitted by the Nominating Committee to the Executive Committee, which body may accept the report, or add other nominees for such offices. If there are other nominees, it will then proceed to select by secret ballot one or more official nominees for each office. (4) Such nominations shall then be announced to the membership, sufficient time being provided before election to permit further nominations by petition when signed by one per cent (63 at present) of entire membership, it being mandatory that nominations by petition be added to the official nominations (see (9), below). Ballots containing official nominees and those submitted by petition shall be mailed to the active membership, and such ballots, postmarked before a specified date, shall be marked and forwarded by the membership to the General Secretary. (6) Within ten days after the specified date the General Secretary shall turn over all such ballots for tallying to a Committee of Tellers consisting of one member selected from each of the eight Sections and one member from the Executive Committee. (7) The Committee of Tellers shall make report to the General Secretary within ten days, showing the result of the ballot. (8) A plurality of votes cast shall elect. (9) Consent of each candidate is to be obtained before placing his name on the ballot. (10) The Sections shall be urged to adopt similar procedures.

Similar Section procedures were established and were published in the *Transactions* of December 1957, with amendments covering Seismology and Hydrology in the *Transactions* of August 1949, page 627. In the summer of 1952, the Executive Committee of the Section of Geodesy voted to permit the nomination of but one candidate for each office of that Section, and at the annual meeting of May 1958, the Section of Tectonophysics took a like step. Some of the other Sections have taken similar action without formally notifying the office of this fact. The procedures will not be repeated in full here. All provide for nominations by petition, the number of member petitioners affiliated with the Section being as follows: Geodesy, ten members; Seismology, 13 members; Meteorology, 25 members; Geomagnetism and Aeronomy, one per cent of those affiliated with the Section (15 members at present); Oceanography, ten members; Volcanology, one per cent of those affiliated with the Section (10 members at present); Hydrology, 25 members; and Tectonophysics, 15 members.

Please note that nominations by petition must include written consent from the nominee, to be transmitted to the office of AGU with the petition.

The following schedule for nominations and elections has been established:

By August 10, 1960, steps (1) to (3) and step (9) of procedure must be complete for the official nominees.

In Transactions of September 1960, publish list of official nominees with explanatory note.

By November 1, 1960, nominations by petition must be in the office of AGU with written consent of nominees.

By December 1, 1960, ballots carrying names of official and petition nominees, will be mailed to the membership. A brief biographical sketch relating to each nominee will accompany, but not be a part of, the ballot.

On December 31, 1960, balloting will close. Ballots must be postmarked not later than that date and be received in the office of AGU not later than January 4, 1960, in order to be counted.

By January 10, 1961, ballots will be turned over to the Committee of Tellers.

By January 20, 1961, results of tally will be turned over to the General Secretary, results to be announced promptly and published in the *Transactions* in March, 1961.

In addition to the election of Union and Section officers, two Regional Branches will hold elections by mail ballot, the nominees to be voted upon only by members in those Regions. The names are also shown in the accompanying table.

Waldo E. Smith, *Executive Secretary*

• NOTICE OF INTENT TO CHANGE BY LAWS—A ballot covering the proposals for changes in the Statutes in an effort to make AGU a more effective instrument, especially in its international functions, has recently been sent to the membership for vote in accordance with Article 13(g) of the Statutes. Concordant changes in the By Laws are essential to implement these changes, and in approving the changes in the Statutes the Executive Committee concurrently approved the concordant changes in the By Laws.

Article 13(b) of the Statutes provides for changes in the By Laws by action of the Execu-

tive Committee on recommendations of the Committee on Statutes and By Laws, with the proposed changes or amendments to be published in the *Transactions* not less than 30 days prior to a meeting of the Executive Committee at which confirming action is to be taken. Notice is hereby given that the following proposed changes in the By Laws will subsequently be acted upon by the Executive Committee at a meeting in accordance with the stipulations of Article 13(b).

The Statutes and By Laws were last published in the June 1959 issue of the *Transactions*, pages 151–155. But one change has been made since then, namely, the addition of Article 3(g) which provides for various types of supporting members, and which was approved by ballot of the membership during the early spring of 1960 (see *Trans.*, June 1960, p. 335).

Relating to Proposal One—By Law 3, second paragraph, now reading "There shall also be a Standing Committee on International Participation consisting of the President, the General Secretary, and the Executive Secretary of the American Geophysical Union and six additional persons . . ." to be changed to read as follows: "There shall also be a Standing Committee on International Participation consisting of the Secretary for International Participation (who shall be Chairman of the Committee), the President, the General Secretary, and the Executive Secretary of the American Geophysical Union, and six additional persons. . . ."

Relating to Proposal Two—By Law 3: Add a new paragraph as follows:

"To execute the affairs of the Union between meetings of the Council and in accord with its policy decisions, an Executive Committee of the Council is established to consist of the President, Vice President, General Secretary, the Secretary for International Affairs of the AGU, and five members of the Council selected from among the voting members of the Council by the National Academy of Sciences upon recommendation of the Council. Only those on this committee who are members of the AGU shall exercise voice or vote in domestic or fiscal matters of the Union."

By Law 7, which now reads "Meetings of the Executive Committee of the *Union* shall be called by the President at least 15 days in advance and a minimum of 12 shall constitute a quorum," changed to read as follows: "*Meetings of the Council of the Union* shall be called by the President at least 15 days in advance and a minimum of one third of the total membership of the Council shall constitute a quorum."

Other changes—the term "Council" shall be substituted for "Executive Committee" wherever that term appears in the Statutes and By Laws *except* as the term relates to the Sections, as in the final paragraph of Article 7 which provides for "Executive Committees" of the Sections of the Union, or as a general term as in Article 9.

Note—The third proposal involves no changes in the By Laws.

• FORTY-SECOND ANNUAL MEETING OF THE AMERICAN GEOPHYSICAL UNION, APRIL 18–21, 1961—The dates for the Forty-second Annual Meeting of the American Geophysical Union at Washington, D. C., are *April 18 to 21, 1961*, inclusive. *Please note that this is a change from the tentative dates announced in the June issue.*

Several sessions of contributed papers on planetary atmospheres are being arranged under the joint sponsorship of the Planning Committee on Planetary Sciences, and the Geomagnetism and Aeronomy Section. The Planetary Sciences Committee also plans separate sessions on other topics of current interest in space research. Details will be given in the December issue of the *Transactions*.

Further general announcements regarding the annual meeting and its various programs will be given in the December and March issues of the *Transactions*.

• PACIFIC NORTHWEST REGIONAL MEETING—The Pacific Northwest Regional meeting is being held at the University of Idaho, Moscow, Idaho, on October 19 and 20, 1960. Calvin C. Warwick of the Dept. of Civil Engineering of the University is Program Chairman. Melvin Ord, U. S. Corps of Engineers, Walla Walla, Washington, is Chairman of the Regional Committee, and Donald Kuehl, U. S. Weather Bureau, Portland Oregon, is Secretary-Treasurer.

• PACIFIC SOUTHWEST REGIONAL MEETING—The Regional Meeting is scheduled for January 26–27, 1961, at the University of California (Berkeley). Persons interested in the program should communicate with one of the members of the Program Committee, which consists of Henry W. Anderson, Chairman, (California Forest and Range Expt. Station, P.O. Box 245, Berkeley 1, Calif.), C. Robert Elford (557 Federal Bldg., San Francisco 2, Calif.), Joseph Kaplan (Univ. of California, Los Angeles 24, Calif.), and Jacob B. Wickham (U. S. Naval Postgraduate School, Aerology Dept., Monterey, Calif.).

• TENTH PACIFIC SCIENCE CONGRESS—The National Academy of Sciences, and the Bishop Museum of the University of Hawaii are co-sponsors of the Tenth Pacific Science Congress, held in Honolulu, from August 21 to September 6, 1960. The program for the Section of Geophysical Sciences, is under the direction of Lloyd V. Berkner, President of the AGU. Organizers for the programs include C. E. Palmer, of the Institute of Geophysics at Univ. of California (Los Angeles), Walter H. Munk, of Scripps Institution, and Thomas S. Austin of the U. S. Fish and Wildlife Service in Honolulu (for the Division of Oceanography). Symposia will be held on Antarctic Research, Oceanography, Meteorology, Glaciology, Tsunamis, Equatorial Circulation in the Pacific, Deep Circulation in the Pacific, North Pacific Circulation, Advances in Oceanography Instrumentation, Radioactive Tracers in Oceanography, Topog-

raphy and Sediments of the Pacific, The Earth's Crust in the Pacific Basin, Volcanism and Plutonism in Relation to Types of Crustal Deformation, Pacific Island Terraces, Tropical Cyclones, Physics of the Upper Atmosphere, and Satellite Meteorology. Proceedings of the Congress will be published.

• INTERNATIONAL CLOUD PHYSICS CONFERENCE—The Australian Academy of Sciences will sponsor an International Cloud Physics Conference, to be held in Canberra and Sydney, Australia, between Sept. 11 and 21, 1961, following the Tenth Pacific Science Congress. The program will cover the following topics: Cloud Growth; Microphysics of Clouds, Condensation Nuclei; Freezing Nuclei, Ice Phase; Rain, Coalescence Process, Radar; Cloud Seeding. Papers will be read by invitation.

• SYMPOSIUM ON MOHOLE AT DECEMBER MEETING OF AAAS—The AGU is co-sponsoring a symposium on Mohole to be held as part of the December meeting of AAAS in New York. The symposium will take place in the Moderne Room of the Belmont Plaza Hotel at 9:00 A.M. on Tuesday, December 27. Harry S. Ladd is chairman.

• TRANSLATION OF RUSSIAN JOURNAL GEODESY AND CARTOGRAPHY—The National Science Foundation has awarded funds to the American Geophysical Union for support of translation and publication of the Russian Journal *Geodesy and Cartography* for 1959. Publication of the first of 12 numbers for that year is in process and the issue will be available soon.

• ADDENDUM—In the reported statement regarding the NAS-AGU symposium on Solar Emissions and the Interplanetary Medium held on April 27–28 (June *Trans.*, p. 334), it was inadvertently omitted that the symposium was also co-sponsored by the Committee on Cosmic-Terrestrial Relationships.

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NATIONAL ACADEMY OF SCIENCES

Number 37 • July 1960

IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs. The Bulletin *also reports on international programs in geophysics and space science that have grown out of the IGY, and on their results.*

Even before the end of the observational phase of the IGY—July 1958 through December 1958—it was apparent that analysis of the great body of accumulated data would require an extended period of time. Moreover, the continuation of many IGY programs during IGC-59, and the numerous successor world-wide geophysics and space-science programs that have grown out of or gained stimulus from the IGY, are adding new dimensions to the over-all geophysical picture. Accordingly, on recommendation of the American Geophysical Union, endorsed by the US National Committee for the IGY, and with support from the National Science Foundation, publication of the *IGY Bulletin* is being continued in order to complete the record of reports on results of IGY and IGY-related studies.

The original aim of the *Bulletin* was primarily to keep participating scientists informed of progress in the United States program and, to the extent possible in the limited space available, in the programs of other countries. During the first few months of publication, however, a large number of students, teachers and other interested persons asked to be permitted to subscribe to the *Bulletin*, and near the end of its first year of publication the *Bulletin* was accordingly made available on a subscription basis. (See back page of this issue for subscription information.)

The *Bulletin* is also reprinted in the *Transactions of the American Geophysical Union*, thus widening its circulation in the scientific community and helping to keep scientists informed of developments in geophysical disciplines related to their own. All in all, nearly 15,000 persons read the *IGY Bulletin* each month.

Through reports on aims, plans, instrumentation and techniques, early *Bulletins* provided background on each IGY discipline, as well as on initial progress in getting IGY programs under way. Also included in earlier issues were short background reports on sub-disciplinary subjects such as whistlers, sunspot numbers, and airglow. Following these first few issues, *Bulletin* reports have been increasingly concerned with scientific results of specific IGY projects. Whenever possible, the reports have been related to the scientists and institutions conducting the experiments; their cooperation has been very largely responsible for the *Bulletin's* success.

With this issue, the *Bulletin* begins its fourth year of publication. Future issues will make available IGY findings not yet reported in these pages, as well as those still to be revealed by analysis of the great storehouse of IGY and IGC-59 data. In addition, plans for related investigations in geophysics and space research, and the results which are emerging from these successor world-wide programs, will be reported. The *Bulletin* will also continue to review developments of interest contributing to the advancement of international cooperation in geophysical research.

—Hugh Odishaw, Executive Director, US National Committee for the International Geophysical Year, National Academy of Sciences.

Electrical Current in the Polar Ionosphere

The following report is based on material prepared by Laurence J. Cahill, Jr., University of New Hampshire. A more detailed account appeared in the Journal of Geophysical Research, *October 1959. Dr. Cahill was associated with the State University of Iowa at the time the studies were made.*

As part of an IGY program to investigate electrical currents in the ionosphere, the State University of Iowa (SUI) conducted a number of rockoon flights in the Arctic, Equatorial Pacific, and Antarctic in the summer and autumn of 1957. *Bulletin No. 25* describes the results of the Equatorial Pacific flights, which penetrated the Equatorial electrojet, and briefly reviews the theory relating ionospheric electric currents to variations in the earth's magnetic field.

During the Arctic region investigations, a magnetometer flight reached the lower ionosphere during a magnetic storm. It provided the first high-altitude magnetic measurements made in or near the auroral zone. This flight, SUI Flight 59, was launched from the helicopter deck of the *USS Plymouth Rock* on August 6, 1957. At the time of launch, 1603 UT, the ship was at about 64°N, 56°W, in the Davis Strait between Greenland and Canada (see Fig. 1). The rocket was fired 80 minutes later, when the balloon was at an altitude of 23 kilometers, and reached a maximum altitude of about 127 kilometers.

Advice and assistance were provided by James A. Van Allen and other SUI scientists. Navy personnel of the *USS Plymouth Rock* cooperated in launching the flights. Ground-station magnetic records, for correlation and comparison, were obtained from Dr. Karl Anderson of the Meteorologisk Institut, Denmark (Godhavn, Greenland, records), and from the Dominion Observatory, Canada (Baker Lake, Canada, records).

Flight Results

Measured values of the earth's magnetic field during Flight 59, after correction for rocket spin, are plotted against altitude in Figure 2. More than 200 individual measurements were made during the flight. Below a height of 90 kilometers, the magnetic record follows approximately the normal inverse-cube decrease of geomagnetic intensity with altitude. An additional decrease, indicated by the divergence of the upward and downward records in Figure 2, resulted from the rocket's horizontal motion to the southeast, toward a region of lower intensity of the total magnetic field.

The abrupt slope-change between 90 and 100 kilometers in the record of the upward leg of the flight marks the rocket's entrance into an electrical current sheet. This slope change, combined with the fact that general

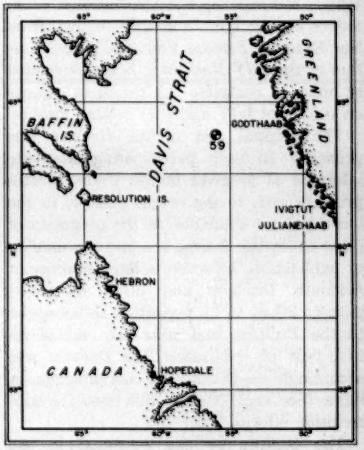

Fig. 1. *Davis Strait Region, Between Canada and Greenland, Showing Location of SUI-IGY Rockoon Flight 59.*

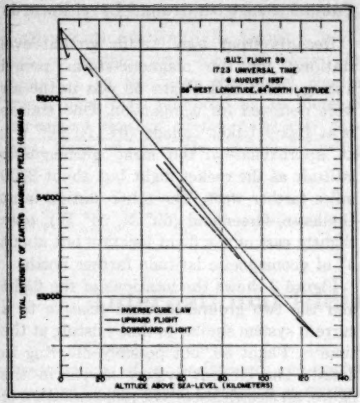

Fig. 2. *Magnetic-Field Intensity Plotted Against Altitude for Flight 59.*

features of the current were found to be the same on both the up and down legs of the flight, even though the two legs were separated horizontally by several kilometers, indicates that the current had considerable lateral extent. A narrow ribbon- or filament-type current, such as those associated with auroras, would produce effects of a different nature.

The gap in the downward record between 117 and 92 kilometers resulted when the angle between the magnetic-field vector and the magnetometer coil became too small for reliable measurements. Rough measurements of proton precession frequencies with a narrow-band frequency analyzer, however, show the record for this gap to be essentially coincident with that for the upward leg. (In the proton precession magnetometer, such as that used on Flight 59, a magnetic-field measurement is obtained as an easily telemetered audio frequency—the gyromagnetic precession frequency of protons in a suitable liquid.)

The slope of the magnetic record at peak rocket altitude did not show a distinct return to that at altitudes beneath the current sheet. Hence, the current layer was not completely penetrated and apparently extended above 127 kilometers. Fluctuations of the measurements near peak altitude, which are easily seen in more detailed records, probably resulted partly from time variations in the magnetic field. Such variations would be more evident near the top of the rocket's flight, where altitude changes are slower.

Intensity and Structure of Current

The magnetic dip angle—the angle between the lines of force of the magnetic field and a horizontal surface—at the flight location is about 80°. Thus, the horizontal current sheet represents a small horizontal vector added to the nearly vertical vector of the total magnetic field.

At peak altitude, the strength of the total magnetic field departs by 90 ± 20 gammas (γ) from the value to be expected in the absence of the horizontal sheet current. The smallest change in the horizontal magnetic field that could cause this change in the total field is 520γ. In this case, the 90γ change in the total magnetic field would occur if the horizontal vector of the sheet current exactly paralleled the horizontal component of the total field but pointed in the opposite direction for positions lying below the horizontal current sheet.

With respect to the flight location, the magnetic north pole is 45°W of geographic north. Hence, the azimuth of the horizontal component of the total magnetic field at the flight location is 315° from true north, or toward the northwest; the direction of the horizontal vector of the sheet current would be 135° true azimuth, or southeast; and the direction of flow of the sheet current itself would be 225° true azimuth, or southwestward (see Fig. 3).

A current producing a 520γ change in the intensity of the horizontal component of the magnetic field at rocket altitude would contribute a variation of 260γ to the horizontal component at ground level. However,

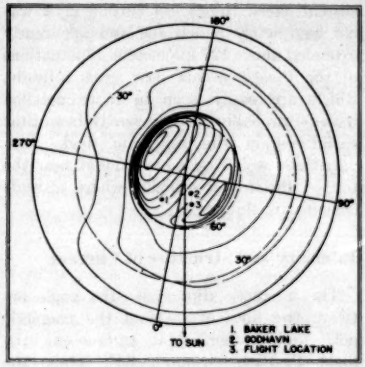

Fig. 3. *Northern Hemisphere Current System for Geomagnetic Storm of May 1, 1933 (after E. H. Vestine). System is centered over geomagnetic pole, and 0° meridian is one running through geographic north pole. Current flows clockwise on dawn side of auroral zone and counterclockwise on twilight side. Locations of Flight 59 and ground stations are indicated by numbers.*

as overhead currents are thought to cause only 2/3 of the total ground-level variation, a total variation of 390 ± 90γ might actually be observed at the ground. In the vicinity of this flight, moreover, an even larger variation might be expected at the ground since the current layer was apparently not entirely penetrated by the rocket. In addition, a current direction appreciably different from 225° would require still larger intensity variations in the horizontal component, as well as greater current density, in order to produce the 90γ change in the total field. A current direction of 165°, for example, would require a current density twice that for the 225° azimuth and would produce a ground-level variation of 780γ.

Assuming an azimuth of 225° for the current direction, the average current density of the current layer would be approximately 11 amperes/km^3. The current density appears to vary with height.

Comparisons with Ground-Level Records

Records from two Arctic ground-level stations, for the magnetic-storm period during which SUI Flight 59 was in the air were obtained for comparison. One station is at Baker Lake, Canada (64° N, 96° W), at approximately the same geomagnetic latitude as the rocket flight but about 2700 miles farther west. The other station is at Godhavn, Greenland (69° N, 54° W), only slightly east of the flight location but about 5° of geomagnetic latitude farther north.

Figure 3 shows the locations of the flight and the two ground stations relative to a current system similar to that existing at the time of Flight 59, but possibly differing in detail. The current system shown in the figure, an electrical-current representation of surface magnetic variations, was prepared by E. H. Vestine for a magnetic storm on May 1, 1933. (Azimuths shown in the diagram do not represent normal geographic directions.)

The horizontal-component variation observed at Godhavn at the time of the rocket flight was approximately 300γ, which agrees reasonably well with the variation of 390 ± 90γ computed for the ground value at the flight location. Some lack of agreement between the two locations might have been expected because of local differences in the density of the overhead current. The equivalent variation at Baker Lake was about 500γ and, because of its location, Baker Lake would have observed the same main features of the magnetic storm two to three hours later than they were observed at the flight location.

Conclusions

The simplest explanation for the results of SUI Flight 59, conducted at a geomagnetic latitude a few degrees above the auroral zone, is that they were caused by a horizontal current layer—the "polar cap current"—flowing southwest. This interpretation is consistent with both the rocket and ground-level observations.

Possibly, however, the flight location was farther south relative to the August 6, 1957, current system than for that shown in Figure 3. In this case, the rocket results might have been produced by an increase in current density as the polar cap current funneled into the eastward-flowing auroral arc; the current direction might then have been south or southeast. Another possible interpretation of the rocket results, pointed out by another investigator, is that they could also have been produced by a horizontal, circular, pancake-shaped current, rather than a sheet current.

International Indian Ocean Expedition

The following material is essentially a condensation of a preliminary prospectus prepared by the Special Committee on Oceanic Research (SCOR) of the International Council of Scientific Unions (ICSU) and released by the White House on June 13, 1960.

An international expedition to the Indian Ocean, one of the least known oceanic regions of the world, will begin late this year and extend through 1964. The Indian Ocean is one of the world's last unexplored frontiers. Since 1873, fewer than two dozen vessels have carried out oceanographic investigations there. Modern techniques have been used only in limited areas, leaving great gaps both in areal coverage and in the nature, intensity, and accuracy of observations. No systematic study has yet been attempted, and the combined profiles of observations reported thus far give only a preliminary picture of the Ocean's behavior and characteristics.

The Indian Ocean offers a vast environmental laboratory extending from polar through tropical waters and divided in its northern part into small oceans, each subject to radical seasonal wind reversals. It is a complete ocean system, yet small enough to be studied as a whole. Thus, it offers unparalleled opportunity for a wide variety of specialized investigations. Although too large for a single nation's efforts, it is ideal for an international cooperative endeavor.

Like the IGY and IGC-1959, the International Indian Ocean Expedition is a many-sided scientific attack on a single area of interest; the Expedition is under the leadership of SCOR (Special Committee on Oceanic Research) of the International Council of Scientific Unions. Scientific responsibility for United States participation is borne by the Committee on Oceanography of the National Academy of Sciences—National Research Council. Key contributions are being made by the Department of the Navy and the National Science Foundation. The Navy is supporting the operation of oceanographic research ships now in use by United States oceanographic institutions. The Foundation is responsible for planning and coordinating Federal support for United States participation in the program, including financial support over and above regular ship operating costs.

The Indian Ocean

Physical Characteristics: Although its 28,000,000-square-mile area constitutes more than 14% of the earth's surface, relatively little is known about the Indian Ocean. Only the most general features of its bottom topography and circulation and of the distribution of its living organisms are known. More than 300 times as many bathythermograph observations have been made in the North Atlantic as in the Indian Ocean; moreover, almost half of this extensive

marine region has had no biological sampling, and in most of the remainder only 1 to 4 observations have been made per 100,000 square miles.

The Indian Ocean has several unique characteristics. Nowhere else in the world is there a similar seasonal reversal of the prevailing wind. That part of the Ocean lying north of the equator is characterized by the two monsoons, one blowing from the northeast for approximately six months and the other from the southwest for the remainder of the year. This phenomenon has a powerful but essentially still-unknown effect upon the currents and upon marine organisms.

Another notable feature is the apparently high productivity of this Ocean. In June 1957, a Russian ship not far from the main trade route between Ceylon and the Gulf of Aden (see Fig. 4) reported millions of tons of dead fish floating in an area some 600 miles long and 120 miles wide extending across the middle of the Ocean. Similar reports came simultaneously from British ships in the region, and during the same year, smaller fish kills were also reported in nearby parts of the Arabian Sea. It is not known how the fish were killed, but the very size of this catastrophe gives some idea of the potential mid-ocean resources, which are currently untapped.

Socio-economic Characteristics: The tropical and sub-tropical regions surrounding the Indian Ocean contain many of the world's densely populated countries. Over a quarter of the world's people live in these countries, and their populations continue to grow rapidly.

Population pressures on the existing food supplies result in the prevalence of protein deficiency diseases in India, Ceylon, Indonesia, Malaya, and parts of the east coast of Africa. Some of the nations bordering the Indian Ocean have a seafaring tradition and conduct extensive coastal fisheries. To feed their growing populations will require expanding these fisheries.

Expedition Design

Participation: Under the non-governmental sponsorship of the International Council of Scientific Unions (ICSU) and its Special Committee on Oceanic Research (SCOR), scientists of the various participating nations will staff vessels provided by marine laboratories of these nations. Scientists from countries where research vessels are unavailable will be invited to work on the Expedition's ships, and special efforts will be made to obtain active participation by each nation bordering the Indian Ocean.

As never before, intensive training and experience in oceanographic research are available to residents of this maritime area. Possibly 20 vessels, with facilities for about 350 scientists, will participate in the Expedition. (Figure 4 is a track chart of the Indian Ocean showing cruises scheduled to be completed by January 1, 1961.) Exchange of scientists between ships, and partial cruises by individuals, will increase the number receiving training and will vary their experience. Data-processing centers and biological classification laboratories are planned to serve as nuclei for post-Expedition scientific development around the Indian Ocean.

As of June 1, 1960, the following nations had formed national committees of SCOR and had announced plans to send ships and scientific parties on the Expedition: Australia, Ceylon, France, German Federal Republic, India, Indonesia, Japan, Pakistan, Union of South Africa, Union of Soviet Socialist Republics, United Kingdom, and United States of America. National committees of the following additional countries plan to contribute scientific parties: China (Taiwan), Denmark, Israel, The Netherlands. Other countries are now forming national committees and may also announce plans to participate.

Timing: The period of peak activity will occur in 1962 and 1963. Preliminary plans will be completed by August 1960 and the

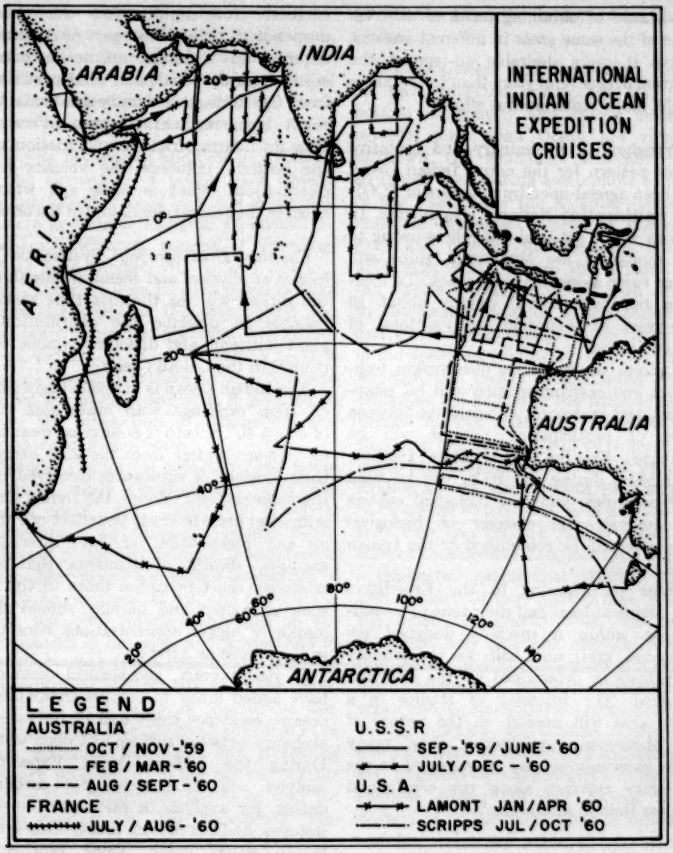

Fig. 4. *Indian Ocean, Showing International Expedition Cruises to be Completed by January 1, 1961.*

first cruises in the coordinated effort will occur in late 1960. The Expedition will continue into 1964 and data analysis will undoubtedly go on still longer. An atlas incorporating the full findings is contemplated.

Because of the present scarcity of information on the Indian Ocean, continuous revision and re-examination of plans will be needed as new data are acquired. Every effort will be made to complete preliminary processing and analysis of data within six to eight months in order to re-direct subsequent cruises. This plan, together with the

importance of obtaining series of observations of the same areas in different seasons, makes it more desirable to spread the program over several years than to conduct a single, major simultaneous effort.

Procedure: A preliminary and tentative cruise pattern for the entire Indian Ocean has been agreed upon by members of SCOR and participating National Committees. In regions where seasonal differences owing to the monsoons are significant, ships will cruise twice along the same track. To complete the pattern will require about 10 ship-years of operation over a total of 180,000 miles.

Uniform standards for observation techniques and instrumentation will be established, and exchanges of scientists between ships of participating nations will be arranged. Existing World Data Centers, established during the IGY, will be used as repositories, and new biological centers for analysis and custody of biological specimens will be established in the Indian Ocean area.

Ships participating in the Expedition will devote at least half their time to investigations within a specially designed coordinated grid, and half to independent investigations determined by the scientists involved. The intensity of studies in a given area will depend on the nature of the phenomena anticipated; thus, many more observations may be expected in the boundary currents along the continental borders than in mid-ocean.

Areas of Study

Physical Oceanography: Several fundamental oceanographic problems can be studied more efficiently in the Indian Ocean than elsewhere because of the seasonal reversal of winds. Thus, understanding the oceanic processes here will contribute to a knowledge of all oceans. It is planned to study many basic questions such as: How long does it take the winds to set up a current? How rapidly does this current deepen with time? What part of the energy required to maintain an ocean current comes from the winds and what part comes from the horizontal density gradients that result from regional climatic differences? How do internal friction, and friction with the bottom, influence the velocity-depth distribution? What is cause and what is effect in the general circulation of the oceans?

Chemical Oceanography: Systematic collection of physical and chemical data during the survey will for the first time make it possible to describe the distribution of plant nutrients and dissolved organic compounds in the Indian Ocean.

The Indian Ocean is in a vast basin closed off from exchange with other seas north of about 40° S. Into it pour great quantities of drainage waters from the land carrying their burdens of substances dissolved from the rocks and soil. Hence, the Indian Ocean is an ideal place to study the effect of run off on the composition of sea water. For example, studies of elements that have relatively short residence times in the sea, such as copper and barium, should show markedly higher concentrations here than in the Pacific or Atlantic.

In recent years, geochemical techniques have added much to our understanding of oceanic residence times and of the rates of exchange between surface and deep waters. During the Indian Ocean Expedition, samples will be collected for carbon-14 dating, for analysis of carbon and oxygen isotopes, and for radium assay. This survey of an entire ocean, using geochemical "tracer" techniques, will permit a much better evaluation of the circulation than has previously been possible.

Meteorology: The meteorological objective is to obtain increased understanding of the energy exchange between sea and atmosphere, particularly near the air-sea boundary. To this end, basic research will be carried out on radiation input and on interaction of

atmospheric pressure, winds, cloudiness, rainfall, and evaporation with temperature, movement, and roughness of the sea. A SCOR working group is drafting a list of desirable objectives in conjunction with various meteorological organizations.

Marine Biology: In addition to its effect on the circulation of near-surface waters, the monsoonal reversal of winds is believed to have important biological repercussions. Under its influence, regions of upwelling and of high productivity should develop, decay, and shift from place to place, causing dramatic changes in the distribution and abundance of marine organisms. The Indian Ocean Expedition observations may make it possible to anticipate these changes. Nowhere else in the world's oceans is it possible to study the interaction of atmosphere and biosphere on such a scale.

Standard biological collections and measurements made systematically over the whole ocean will define its biological "structure," the three-dimensional distribution of plants and animals. Integration of these observations will permit assessment of the living resources. It will also provide the basic biological information—such as the distribution of fish eggs and larvae, and of fish food—that is essential to the eventual understanding of fluctuations in the abundance and availability of commercial fish.

Since World War II, great advances have been made in techniques for measuring primary production of the minute organic matter that constitutes the basic food for larger marine life. The widespread, systematic use of these methods by the ships of the Expedition will help in assessing, for the first time, the fertility of the Indian Ocean.

Marine Geology and Geophysics: Except for data collected during the IGY, the bottom topography and crustal structure beneath the Indian Ocean are virtually unknown. Old soundings delineate major structural components comparable to those of the Pacific and the Atlantic—trenches, undersea mountain ranges, a mid-ocean swell, and, possibly, fracture zones. Marked differences exist between the Atlantic and the Pacific Oceans, however, with respect to the arrangement of these components and to their relationship to the structures of the bordering continents. It is not known whether the Indian Ocean more closely resembles the Pacific or the Atlantic ocean. Precise modern soundings, in addition to clarifying this question, will be of immediate use in providing a base map for all the other studies as well as the data necessary for navigational charts. It is even possible that they may uncover rich shallow-water fisheries at considerable distances from shore.

Integrated geophysical studies—of the areal pattern of heat flowing from beneath the crust, the gravity field, the crustal thickness, and magnetic characteristics of the oceanic and border areas—will furnish basic information related to problems of ocean and continent development. Intensive coring, dredging, and bottom photography will yield data on processes of sedimentation and productivity; on climatic and magnetic changes during the last several million years; and on the distribution of manganese nodules, which are potential ores of manganese, nickel, and cobalt.

Geologic Investigation of the Central Horlick Mountains, Antarctica

The following material is based on a more detailed report by William E. Long, glaciologist at IGY Byrd Station during the 1957–58 season and member of the 1958–59 over-snow traverse team from Byrd Station. The original report was issued by the Ohio State University Research Foundation as USNC-IGY Antarctic Glaciological Data Report Number 2, Part VII, Preliminary Report of the Geology of the Central Range of the Horlick Mountains, Antarctica, *September 1959.*

The Horlick Mountains extend eastward from the southeast corner of the Ross Ice Shelf for a distance of about 250 miles. They lie approximately along the 85° S parallel of latitude roughly between 130° and 85° W longitude (see Fig. 5). Prior to the IGY, the Horlick Mountains had been seen only a few times and from considerable distances. Hence, very little was known about their exact location, extent, height, and geologic nature.

During a reconnaissance flight over the route of the Byrd Station 1958–59 IGY over-snow traverse, which was scheduled to pass along the front of the Horlick Mountains, the sedimentary aspect and structure of the central portion of the mountains was noted. Plans were made to include a visit to this region during the traverse.

The traverse party of six left IGY Byrd Station in three Sno-Cats on November 1, 1958, to make seismological, glaciological, and geological investigations of the ice cap and of projecting bedrock areas (see *Bulletin No. 25*). The traverse reached a position about three miles from the mountains in early December, and a base camp was established. Four members of the party, C. R. Bentley (traverse leader), J. B. Long, F. L. Darling, and W. E. Long, then made a reconnaissance geological investigation of the mountains. They climbed 4000 feet to the summit of Mount Glossopteris, tentatively so named for the characteristic plant fossils found there, making rock-sample collections and measuring elevations and attitudes of the rock beds. The summit was marked with a six-foot redwood beam, and a container with the party identity and date was placed at the base of a small cairn built on the highest rock surface, just west of the snow summit.

Surveying and mapping of the mountains here and along the entire traverse was accomplished by US Geological Survey cartographer William Chapman, using a theodolite. G. A. Cooper helped in later analysis by dating the fossil brachiopods (marine, shelled animals); James Schopf, US Geological Survey, assisted with paleobotanical dating and advice; Samuel Treves, University of Nebraska, advised and aided with rock identifications and interpretations; and Warren Hamilton, US Geological Survey, analyzed a basement-rock specimen.

Geography

The Horlick Mountains are a continuation of the mountain chain that extends from Cape Adare, at the northeast end of Victoria Land, along the eastern border of Victoria Land to the Queen Maud Range, south and southeast of the Ross Ice Shelf (Fig. 5). The structure and rock types are strikingly similar throughout the entire mountain chain. The mountains are massive, tabular blocks, in most places bounded on the north by imposing escarpments and sloping gently toward the south.

The area marked Horlick Mountains on older maps consists of three ranges, each including numerous peaks. The westernmost range has the highest summits, reaching elevations of about 12,800 feet, with approximately 5000 feet of relief between the ice-cap surface and the summits. Peaks of the

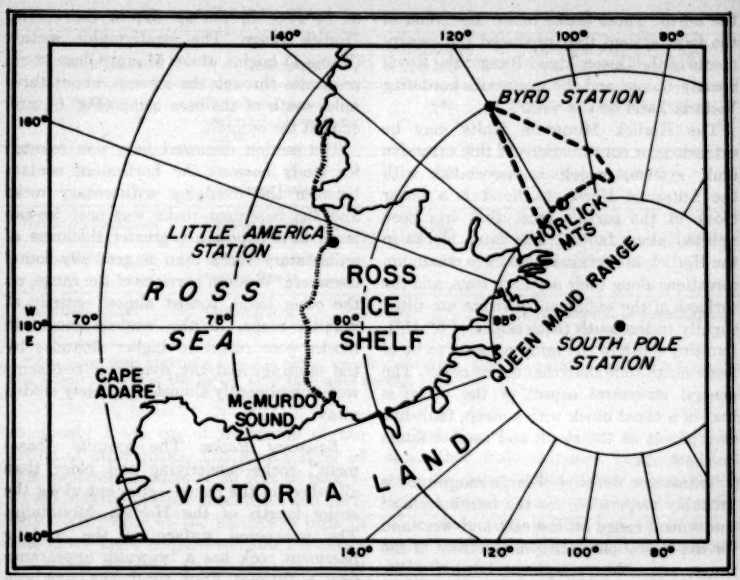

Fig. 5. *Route of 1958–59 Byrd Station Traverse, (dashed line), Showing Position of Horlick Mountains and Location of Area Studied (half-shaded circle).*

central range are generally about 10,000 feet in elevation, with 4000 feet of relief between the peaks and the snow surface. The eastern Horlick range consists of 8000- to 9000-foot peaks and relief is about 3000 feet.

The central Horlick range, in which the area of study was located, is about 20 miles long and 5 to 10 miles wide. Peaks of the central range form an asymmetrical arc concave toward the south. Inside this mountain arc, is a raised ice plateau with an elevation of about 8000 feet and a width of 10 to 15 miles.

Bedrock is well exposed on mountain slopes, where the strong winds prevent accumulation of snow. Moreover, no lichens or other plant life were seen on any of the exposures.

Since air temperatures in the area never rise above freezing, no water is available to form streams or lakes. Hence, no erosional features caused by running water are present. In addition, little chemical erosion seems to occur. The dominant erosional process is the scouring and abrasive action of the ice cap flowing around the peaks and of the valley glaciers that have formed within the mountains and, carrying debris from the mountains, drain out to meet the ice cap.

Geologic Structure

The elevation and shape of the Horlick Mountains is governed by uplift and tilting of major blocks of the earth's crust along great faults, or crustal fractures, which created the steep, 5000- to 10,000-foot escarpments bordering the mountains on

the north. These faults follow the trend of the fault system that produced the escarpments of the Queen Maud Range, the Royal Society Range, and the mountains bordering Victoria Land on the west.

The Horlick Mountain faults may be extensions or continuations of this extensive fault system, which is associated with the Antarctic Horst. (A horst is a linear block of the earth's crust that has been uplifted along faults.) The fault blocks in the Horlick Mountain region have maximum elevations along their northern rims, and the surfaces of the sedimentary strata are tilted slightly to the south (with slopes of 5°–15°). Faulting south of the range appears to be of lesser magnitude than that to the north. The general structural aspect of the range is that of a tilted block with a steep, fault-line escarpment on the north and smaller faults on the south.

Transverse faulting of large magnitude is probably responsible for the termination of the central range on the east and west and for the lateral off-setting of the front of the range, since the escarpment bordering the eastern half of the central range is farther south than that of the western half. (The western Horlick range presents the same aspect.) Minor faults appear to parallel the main escarpment.

The rock strata of Mount Glossopteris are relatively undisturbed and dip 3°–20° toward the south. The only break in the general dip is in a local fault zone on Mount Glossopteris, where dips as high as 40° to 50° were measured. The attitudes of the beds were generally consistent throughout. Moreover, no major unconformities other than that between the base of the sediments and the surface of the basement rocks were observed. Hence, it is assumed that the rock sequence from the basement rocks to the Upper Beacon series on the summit of Mount Glossopteris is continuous.

Rock Types

A detailed study was made of the sequence of rock layers—the "stratigraphic section"—at 84°44.8′ S, 113°44′ W, in the central Horlick range. The stratigraphic section (Table 1) begins where Mount Glossopteris protrudes through the ice cap, about three miles south of the base camp (Fig. 6), and ends at the summit.

The section discussed here was selected for study because the horizon of contact between the overlying sedimentary rocks and the basement rocks was near ice-cap level, thus exposing a greater thickness of sedimentary rocks than is generally found elsewhere. Western portions of the range, on the other hand, consist almost entirely of granitic rocks, as the western mountain blocks were raised to higher altitudes by the faulting, and the overlying sediments were subsequently almost completely eroded away.

Basement Rocks: The granitic "basement" rocks—underlying and older than all others in the region—crop ont along the entire length of the Horlick Mountains. The weathered surface of the granitic basement rock has a brownish appearance from a distance. Fresh specimens have been identified as quartz monzonite—an igneous rock formed at great depth and having quartz and both plagioclase and orthoclase feldspar as major constituents. The rock is pinkish in color, contains considerable biotite, and is porphyritic in texture, having crystals of pink orthoclase up to two inches long in the finer-grained groundmass of the rock. Lighter and darker dike-like masses (see below) of igneous rock cut through the quartz monzonite in places.

The upper surface of the basement rock is gently rolling and appears to be an old erosion surface that was later submerged beneath encroaching seas and upon which the overlying sediments were subsequently deposited.

Oldest Sediments: Directly above the basement rocks lies an 1175-foot-thick sequence of Devonian sediments, consisting primarily of graywackes—sandstone-like rocks, predominantly gray in color and

Table 1. Mount Glossopteris Rock Sequence

Rock Unit	Description	Thickness (in feet)	Geologic Period and Age (in millions of years)*
Upper Beacon	Sandstone, shale, coal beds, Glossopteris fossils	1860	Permo-Carboniferous (180-255)
Lower Beacon	Sandstone, shale, a few coal beds	490	Carboniferous (205-255)
Unnamed formation	Dark-gray, silty shale	385	?
Unnamed formation	Graywacke, sandstones, marine fossils	1175	Devonian (255-315)
Basement rocks (unnamed)	Granitic rock	?	Early Paleozoic or Precambrian (510+ if Precambrian)

* Age range from beginning to end of period, or periods, is given. Ages after chart of Major Stratigraphic and Time Divisions in Use by the U. S. Geological Survey, 1958.

commonly made up of fragments of the debris of other rocks. The lowest layer of this sequence consists of 90 feet of poorly-sorted, quartz-feldspar sandstones and finer, silty beds. Some of the sandstone beds in this lower layer contain calcium carbonate cementing material and brachiopod fossils characteristic of Lower Devonian age (see Table 1).

Lying conformably (parallel and with no indication of an intervening erosional interval) upon these basal sedimentary rocks are beds of graywacke approximately 910 feet thick. The graywacke is mostly medium to dark gray, poorly sorted, and contains occasional 10- to 30-foot-thick beds of more resistant rock which form step-like features in the graywacke. The base of the graywacke series is marked by a poorly-sorted boulder conglomerate, with boulders up to one foot in diameter as well as quartz and other smaller rock grains. At the upper boundary of this series is a platy, silty shale, 175 feet thick, which breaks neatly along bedding planes and forms flat, pavement-like surfaces. Fossil worm burrows were found in the platy shale. The graywacke series and the platy shale are Devonian in age (see Table 1).

Dark-Gray Shale: Above the platy shale is another shale sequence. It is very dark gray in color, splits easily along closely spaced, parallel planes, and crumbles easily. This shale unit is 385 feet thick and is quite uniform throughout. It is characteristically soft and easily eroded.

The Beacon Group: The Beacon group, lying between the dark-gray shale and the summit of Mount Glossopteris, is the best known of all Antarctic sedimentary rock units. Exposures of rocks of the Beacon group occur along the entire length of the mountainous belt known as the Antarctic Horst. Their wide distribution in Antarctica is further suggested by the discovery of similar rocks in the Theron Mountains, in Coats Land on the east side of the Weddell Sea, by the British Trans-Antarctic Expedition.

The Beacon group was named by H. T. Ferrar, geologist with the British National Antarctic Expedition, 1901–04. In outcrops in the McMurdo Sound area Ferrar noted the nearly horizontal attitude of the beds, their sandy composition, and that they contain plant fossils. He also noted that the Beacon group is intruded in many places by sills and dikes of "dolerite." (Sills and

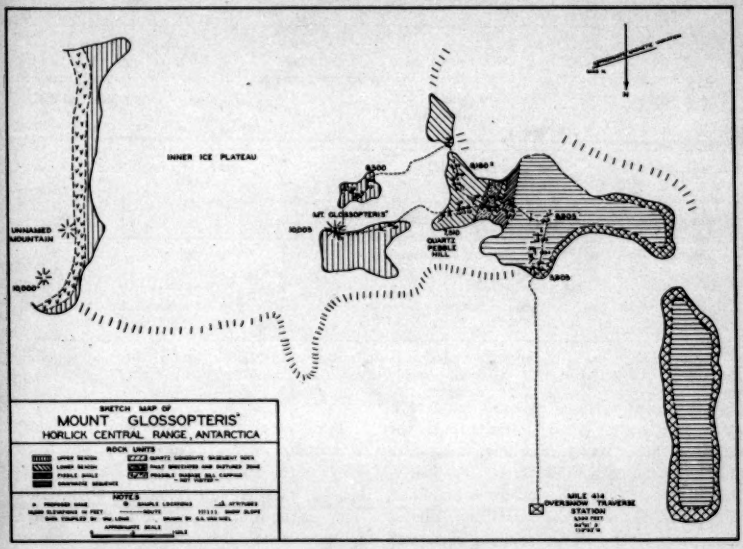

Fig. 6. *Reconnaissance Geologic Map of Mount Glossopteris Region, in the Central Range of the Horlick Mountains. By W. E. Long.*

dikes are igneous materials intruded in the molten state into older rock formations; sills are parallel to the bedding or foliation planes of the intruded rocks, while dikes cut across them. Dolerite is rock of basaltic composition.) Since then, nearly every expedition to this portion of Antarctica has found the Beacon to be as originally described. In other areas of Antartica, the diabase (dolerite) sills reach thicknesses of 2000 feet and account for more than half of the total bedrock thickness. The Beacon group in the central range of the Horlick Mountains, however, differs from occurrences in other areas in that no diabase is present (with one possible exception, described below). In all other respects the Beacon in the central Horlicks resembles descriptions of it from other localities.

The upper limit of the Beacon group has been removed from the summit of Mount Glossopteris by erosion. A mountain a few miles from Mount Glossopteris showed a change in rock types in the upper 200 feet. This capping rock appeared to have igneous features and could, therefore, be a diabase sill capping the Beacon group. On the basis of relative positions, the summit of Mount Glossopteris appears to be near the top of the Beacon group, as seen on the nearby mountain.

Plant fossils (*Glossopteris* leaves and *Dadoxylon* wood) and small beds of coal and shale have also been described from all exposures of the Beacon group. The sandstones commonly show cross-bedding and current ripples, indicating that deposition took place under terrestrial conditions in an arid climate and that the source area was relatively near at hand.

The Upper Beacon is cyclic in nature, with sequences of sandstone, shale, and coal beds being repeated several times through a section 1860 feet thick. The coal beds, ranging in thickness from about one inch to one foot, are usually closely associated with slates. Cross-bedding and plant remains are common in the sandstone. The largest of the plant stems found was approximately 12 feet long and more than 12 inches in diameter. The cyclic nature of the Upper Beacon and the relative abundance of coal beds are not characteristic of the Lower Beacon.

Geologic History

Basement Rocks: The oldest rocks exposed in the central Horlick Mountain region are the quartz monzonite basement rocks. This intrusive igneous material was probably emplaced beneath the earth's surface in early Paleozoic or Precambrian time. Erosion then removed the overlying rocks and produced the rolling surface on which the younger sedimentary rocks were later deposited.

Sedimentary Deposits: The sedimentary rocks in the Horlick region form a sequence typical of the continental side of a geosyncline. (Geosynclines are extensive, usually linear regions of subsidence in the earth's crust in which great thicknesses of sediments and volcanic materials, carried down from bordering land areas, slowly accumulate.) The earliest sedimentary rocks in this region probably represent beach deposits layed down by an encroaching sea during the early Devonian period. The continuing land subsidence that permitted this marine encroachment was accompanied by uplift of bordering regions, which served as sources for the graywackes that were being poured into the subsiding basin.

The coarser rocks of the Lower Beacon group, which were the next to be deposited, probably reflect lowering of the source areas by erosion, filling of the basin, retreat of the seas, and the on-set of an environment that was swampy and marshy or, possibly, predominantly terrestrial. Minor fluctuations of the base level of erosion probably account for the cyclic nature of the Upper Beacon. The plant fossils of the Beacon indicate that the Horlick Mountain region was dry land again during the Carboniferous and Permian periods.

Post-Depositional History: After the Carboniferous and Permian periods, the Horlick Mountain region remained generally above sea level. The present position of the mountains may reflect several periods of uplift, the most recent of which took place in the Tertiary or Quaternary periods (i.e., within the last 60 million years), when the last upheaval raised and tilted the blocks to form the present mountains.

Summary and Conclusions

Rocks collected from outcrops in the central range of the Horlick Mountains, by members of the 1958–59 IGY oversnow traverse from Byrd Station, apparently represent a continuous, nearly undisturbed sequence, the upper portion of which has been named the "Beacon group" in other Antarctic localities.

Beneath the Beacon sediments is a sequence of fossiliferous Lower Paleozoic marine rocks. It appears that the only other fossiliferous Paleozoic marine rocks found in the Antarctic have been erratics—rocks moved from their places of origin, usually by ice—containing Cambrian (430–510 million years ago) and Devonian fossils.

Rocks resembling the graywacke of the Horlick Mountains have also been observed in other parts of Antarctica and it has been suggested that some of these may be Paleozoic in age; unfortunately, these rocks do not contain fossils and are therefore difficult to date.

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A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs. The Bulletin *also reports on international programs in geophysics and space science that have grown out of the IGY, and on their results.*

Severe Sea Surges at Barbados

The following material is based on a more detailed report by William L. Donn and William T. McGuinness, both of the Lamont Geological Observatory of Columbia University, which was published in the December 1959 issue of the Journal of Geophysical Research.

To obtain a better understanding of both long- and short-term variations in sea level, networks of island observatories were set up in the Atlantic and Pacific Oceans as part of the IGY Oceanography Program. Tide gauges and wave meters at these observatories kept a continuous record of sea-level fluctuations; standard meteorological measurements were also obtained to provide data on possible relationships between atmospheric and oceanic phenomena. (*Bulletin No. 22* reports on some preliminary results of the Atlantic Ocean investigations, which were conducted under the direction of the Lamont Geological Observatory, and refers to earlier reports outlining the island observatory program and describing some of the instrumentation used.)

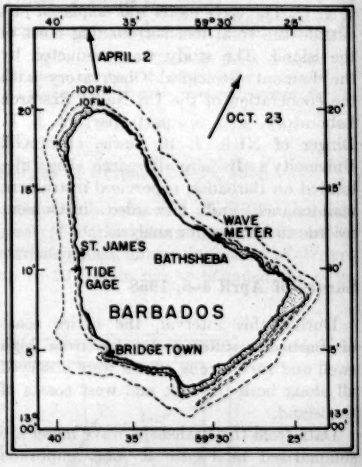

Fig. 1. *Island of Barbados, British West Indies. Instrument locations and directions toward swell-generating regions of North Atlantic storms (arrows) are shown.*

The island of Barbados, in North Atlantic equatorial waters near the lower end of the British West Indies, was the site of an island observatory during the IGY (see Fig. 1). The coasts of Barbados, as well as of other West Indian islands, have frequently suffered successions of unusually high and often damaging sea waves. These sea surges were not associated with local or Caribbean storms, and attempts to explain them as tsunamis—great sea waves produced by submarine earthquakes or volcanic activity—or as the result of submarine landslides, have been unsuccessful.

The lack of precise observational data on the physical characteristics of such waves has in the past been a major deterrent to a satisfactory explanation of their origin. On the basis of data obtained at the

Barbados IGY island observatory, however, it is now apparent that these severe coastal disturbances result directly from high sea swells radiating from remote storms over the North Atlantic at middle latitudes. This report describes and analyzes several occasions during the IGY when such high and damaging surf conditions occurred along the coasts of Barbados.

Observations used in the investigation were obtained by a wave meter installed in about 80 feet of water off Bathsheba, on the east coast of Barbados, and by a standard tide gauge at St. James, on the west coast (Fig. 1). The wave meter was emplaced just outside the coral reef surrounding most of the island. The study was conducted by the Lamont Geological Observatory with the cooperation of the US Naval Research Laboratory, and, in particular, of J. E. Dinger of NRL. J. B. Lewis, of McGill University's Bellaire Research Institute, located on Barbados, supervised instrument maintenance and forwarded instrument records to Lamont for analysis.

Surges of April 4–6, 1958

During this interval, the entire coast of Barbados suffered damage from high swell and surf; strong effects were observed all along both the east and west coasts of the island.

Data from the Bathsheba wave meter are summarized in Figure 2. The amplitude curve, which represents the significant wave height (the average of the highest one-third of the waves), shows the first increase above background just prior to 2400 GMT on April 3. Maximum wave height occurred at about 1800 on April 5, almost two days after the onset. Wave period, which increased at about the time of the first height increase, reached a maximum of 15 seconds shortly before the time of maximum wave height. (The plotted period represents the average of the periods of the dominant waves measured over a 10-minute interval every two hours.)

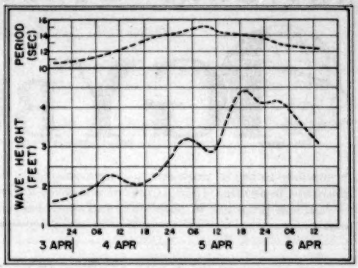

Fig. 2. *Record of Wave Height and Wave Period from the Bathsheba Wave Meter, April 3–6, 1958.*

The St. James records for this interval reinforce those obtained at Bathsheba. Comparison of the records from both locations shows that the interval of high waves occurred at nearly the same time on both sides of the island.

It thus appears that the damaging surf originated from typical but strong ocean swell, and this, in turn, suggests a probable storm origin. Although no directional data are available for the swell, the absence of any tropical or subtropical storms in nearby oceanic areas indicates a more remote origin. According to North Atlantic weather charts, a large, intense, extratropical cyclone traveled northeastward after originating off Cape Hatteras on March 31. On April 1 and 2, 45- to 50-knot winds prevailed over a fairly long southerly fetch (distance over the water) in the western half of the storm. Figure 3 shows the storm's position on the morning of April 2.

The relation of the Barbados swell to this storm is shown by using travel times for the waves corresponding to two points on the wave curves (Fig. 2), one near the beginning of the heightened wave activity and one at maximum. The wave period at 0800, April 4, was 11.5 seconds. Using a group velocity of 16.75 knots, position arcs (isochrones) were constructed along a line extending from Barbados in the direction from which the swells were coming (see

Fig. 4). The arcs mark prior intervals of 12 hours.

When compared with the positions of possible generating areas shown on the weather charts, the isochrone for 1800, March 31 (A, Fig. 4), appears to correspond well with the position of the storm at that time. Similarly, if a group velocity of 22.5 knots is used for the 15-second waves at 0900 on April 5, it is evident that the isochrone of the wave position for 0600, April 2 (B, Fig. 4), intersects the intense storm area at about the same time. A discrepancy of 2 to 3 hours in precise meeting of the waves and storm is well within the experimental error of the procedures involved, particularly as the weather charts are issued at only 6-hour intervals.

As the storm moved northeastward, the position of best fit kept pace. It thus seems definite that the Barbados swell of April 4–6, 1958, originated in this coastal storm and that the longer-period and higher waves were generated later in the storm, when the storm had moved northeastward and was at a somewhat greater distance from the station.

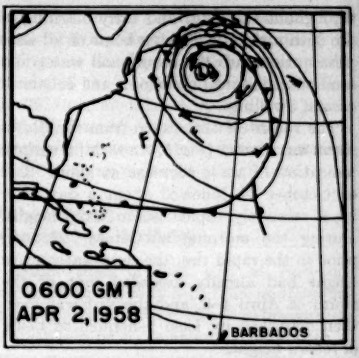

Fig. 3. *Weather Chart of North Atlantic Storm on April 2, 1958. Isobars indicate six-millibar pressure intervals; arrows fly with the wind, each full barb representing a speed of 10 knots and each flag 50 knots.*

Surges of October 24–28, 1958

On October 25 and 26, 1958, the east coast of Barbados was again battered by extremely high, unusually severe surf. Waves up to 30 feet in height pounded the coast

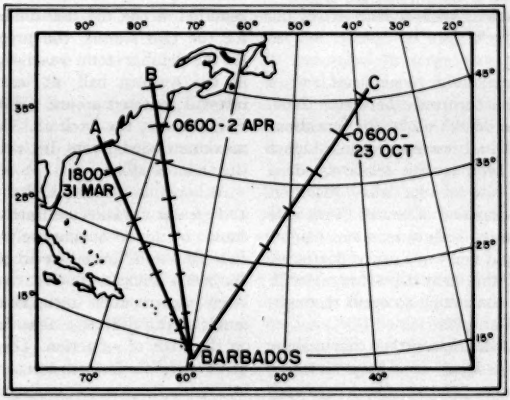

Fig. 4. *Position Arcs (Isochrones) for Barbados Storm Swell in Early April (paths A and B) and Late October (path C), 1958.*

throughout the night and early morning of the 25th and 26th. Fishing boats of all sizes were hurled onto the beach, and water and sand cascaded into the rooms and cellars of coastal dwellings.

The record of this storm from the Bathsheba wave meter (Fig. 5) showed the earliest indication of wave increase at about 1200 on October 24, followed about a day later by a relatively rapid rise in wave height. During the morning of October 25, and prior to the rapid rise, the deep-water wave height had already exceeded that of the storm of April 4–6, and the surf was even then described by local fishermen as being of record height.

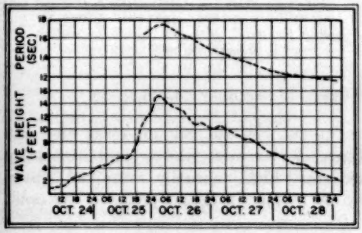

Fig. 5. *Record of Wave Height and Wave Period from the Bathsheba Wave Meter, October 24–28, 1958.*

Although maximum significant wave height, which occurred between 2400, October 25, and 0600, October 26, was about 15 feet, individual waves reached higher than 18 feet even in the relatively deep water at the site of the wave recorder. Maximum wave period of nearly 18 seconds was simultaneous with maximum height. Both wave height and wave period decreased slowly during the next three days, with record heights continuing to occur throughout October 26 and 27.

The North Atlantic weather charts show the growth and decay of a large, intense, low-pressure area (extratropical cyclone) between October 22 and 25. During the two days of maximum intensity (October 23 and 24) the storm moved very slowly, with the center remaining close to 40° N, 40° W.

Using a group velocity of 27 knots for the waves of maximum period at the time of Barbados wave maximum, it was found that good coincidence of swell and storm occurred during the morning of October 23 (C, Fig. 4). The swell isochrone for 0600 intersects the storm area at just that time, indicating that the maximum Barbados swell probably originated in this storm at a time when the storm was large and intense. As the storm was nearly stationary, the resulting waves were more strongly affected by the fetch, duration, and speed of the wind than if the storm had moved at the more usual 20- to 30-knot speed toward the northeast.

No reports of unusual surf were made for the west coast of Barbados during this interval of record seas along the eastern shores, as was the case on April 4–6.

Comparison of April and October 1958 Storm Effects

The swell at Barbados from the storms of April and October 1958 differed in both magnitude and distribution. Although the reported winds did not differ significantly for the two storms, the pressure gradient for the October storm was distinctly stronger in the western half, at least during the interval centered around 1800, October 23. Furthermore, the fetch and the duration of maximum winds, were distinctly greater for the October storm.

Although somewhat higher wind speeds, and greater duration and fetch of the winds, could at least qualitatively account for some of the difference between the swell at Barbados associated with these storms, a large part remains unexplained. However, much of the difference may be explainable on the basis of refraction. The directions of wave travel for the two storms are indicated in Figure 1 by arrows pointing toward the storms. Clearly, the swell from the April storm, arriving from the north, would

spread southward along both the east and west coasts of Barbados but would suffer considerable refraction in the process of developing surf along the shore. It is quite evident from air photographs of refracted swell that the resulting extension of the wave crests may result in considerable decrease in amplitude. Some change in period is also likely.

Swell from the October storm, arriving from the northeast, would strike much more directly on the east coast, with relatively little refraction, while the west coast would be mostly sheltered from this swell. Although severe extratropical cyclones with appropriate fetch to produce high Barbados rollers, as in early April 1958, may occur in North Atlantic coastal areas a few times a year, mid-ocean storms like that of October 1958 are much more rare, as are cases of extremely high Barbados swell such as that generated by this storm.

Qualitatively, at least, the difference between the distribution and magnitude of the swell of the April storm and of the October storm thus seems explainable on the basis of refraction and sheltering. Adequate shore data are not available at present for evaluating these effects quantitatively.

Tidal Effects

The relationship between the occurrence of storm swell and the phase and range of tide seems also to be of importance in determining shore effects. The difference between the range of the spring and neap tides at Barbados (St. James) is about two feet. (Spring-tide range is three feet and neap-tide range is one foot). The high surf of April 4–6 occurred at exactly the time of spring tide and that of October 25–26 occurred about halfway between spring and neap tides.

Normal swell, particularly at times of low tide or neap tide, tends to break on the reef and leave the shore unmolested. Swell arriving at spring tide can clear the reef and break on shore during high water. High swell arriving during the high phase of spring tide thus becomes a threat. Even the effects of the very high swell of October 25–26 were modulated by the tide phase, with the severest effects reported on the afternoon of the 25th and early morning of the 26th, at the times of high tide.

Other Recent Surges Observed at Barbados

Other cases of high surf at Barbados occurred during May 3–5, 1958, and December 7–9, 1957. Owing either to incomplete installation or to temporary breakdown of wave-recording equipment, complete wave records of these storms were not obtained. However, on the basis of available data, the appropriate North Atlantic weather charts were examined and it was found that two intense storms existed in the western North Atlantic at these times. Winds exceeding 50 knots and similar in location and behavior to those of the storm of April 1958 were reported.

Conclusions

Storm rollers and high surf at Barbados and in the Lesser Antilles in general, that are not related to local storms, appear to be generated in large and intense extratropical cyclones at middle latitudes in the North Atlantic Ocean. By simply monitoring weather charts of the North Atlantic Ocean it should be possible to make qualitative forecasts of the arrival of the storm swell in the Barbados area at least two or three days in advance. The swell may be expected to be especially high if it arrives during spring tides.

Further detailed study, including wave-spectrum determination and refraction corrections, will be necessary in order to make possible the quantitative forecasting of the precise arrival time, height, and period of the storm swell.

From the studies conducted thus far, it appears that storms to the north (off the

eastern coast of the United States) generate swell that affects both sides of Barbados but suffers considerable amplitude loss from refraction. It is probable, on the other hand, that swell from mid-ocean storms of great intensity principally strike the eastern coast with an effect that is a function of size, intensity, and route of travel of the storm.

The explanation of the Barbados sea surges as originating in distant storms places them in a class with the well-known rollers of the South Atlantic and Indian oceans. These long-period rollers, also of distant-storm origin, can produce breakers and surf reaching 40 feet in height on the coasts of islands in these oceans.

Radioactive Tracer Studies of Mixing in the Atlantic Ocean

The following material is based on a report by V. T. Bowen, of Woods Hole Oceanographic Institution, and T. T. Sugihara, of Clark University. The original, more-detailed, account appeared in Nature, *April 2, 1960.*

The circulation and mixing of ocean waters are extremely important to man, exerting a very powerful influence on climate and largely controlling the fertility of marine life. Man's knowledge of this circulation and mixing is still quite limited, but in recent years a new tool—radioactive "tracers"—has been found which promises to add greatly to this knowledge. These tracers, consisting of minute particles of natural and artificial radioactive nuclear materials, can be followed for great distances in the atmosphere and oceans, providing much new data on the space and time patterns of their motions.

The IGY program included radioactive-tracer studies of both the air and the oceans. *Bulletins 14* and *16* present background information on these studies, and some preliminary findings. The present report is concerned with some results in the marine program. The work described was part of a Woods Hole Oceanographic Institution IGY project supported by the National Science Foundation, the Office of Naval Research, and the Atomic Energy Commission.

In previous investigations of the geochemistry of carbon dioxide in the oceans, and of ocean mixing as determined by carbon-14 distribution, the ocean waters have customarily been separated into shallow surface reservoirs and deep reservoirs. The shallow surface reservoirs are assumed to be well mixed, while the deep reservoirs are assumed to be only slowly renewed from the surface.

In some applications, the quantitative expression of this two-reservoir concept is extremely sensitive to the depth of the surface reservoir and to its rate of mixing with the waters below it. These factors can be determined by use of relatively short-lived radio-isotopes added to the surface layer from above. In both the North and South Atlantic, strontium-90 (half-life 28 years, as compared to 5568 years for carbon-14) permits such determinations as it has been added to the sea water in measurable quantities only at the surface. Moreover, this strontium-90 is completely soluble in sea water and the concentration is not changed significantly by either biological or chemical processes. Its vertical

Table 1. Strontium-90 in the North and South Atlantic

Depth (meters)	Location and Date						
	15° 49′ S, 35° 50′ W (4/1-2/57)	8° 26′ S, 7° 45′ W (3/1/57)	16° 15′ N, 43° 37.5′ W (11/22/57)	36° 23′ N, 70° 33′ W (7/13/57)	31° 15′ N, 68° 10′ W (12/8/57)	34° 30′ N, 65° 42′ W (7/11-12/58)	34° 39′ N, 67° 24′ W (7/15-16/58)
0	4.1 ± 0.5	5.0 ± 1.0	6.3 ± 0.6	10.5 ± 0.6	10.9 ± 0.6	7.6 ± 0.6	9.1 ± 0.6
100			5.4 ± 0.5		7.7 ± 0.6	13.0 ± 0.7	8.2 ± 0.6
300		2.4 ± 1.0				11.8 ± 0.9	5.5 ± 0.5
400			2.2 ± 0.3		3.9 ± 0.6		
500				4.1 ± 0.6		7.3 ± 0.4	6.4 ± 0.5
700		<0.3			2.3 ± 0.4	3.7 ± 0.5	3.4 ± 0.5
1000	1.5 ± 0.6			<1.0		<0.9	1.7 ± 0.3
1200			1.6 ± 0.8				

Note: Concentrations of Sr^{90} are given in disintegrations per minute per 100 liters of ocean water. Deviations indicated are those expected from counting statistics only.

transport depends, therefore, entirely on the vertical component of motion of the water in which it is dissolved.

As part of a continuing program of analysis of marine radio-isotopes, a number of series of measurements have been obtained of the change with depth of the strontium-90 concentration. Table 1 includes the results of seven series of strontium-90 analyses, showing very significant radiostrontium concentrations at depth in the Atlantic Ocean, both north and south of the equator. Although there are still too few analyses for very precise determinations, an average concentration of about half the surface value is indicated for depths between 300 and 700 meters. The upper 100 meters, as generally assumed, appears well mixed, and the concentration falls off sharply between 100 and 300-to-400 meters. Appreciable concentrations are common at depths between 1000 and 1200 meters, but the investigators found no measurable radiostrontium in samples from depths of 3000 to 5000 meters.

In the water columns sampled thus far, there appears to be three to four times as much total strontium-90 below a depth of 100 meters as above. It is reasonable to assume, moreover, that all of this strontium-90 has been added since mid-1954. Thus, the possibility that this vertical transport may have taken place by sinking along density surfaces appears to be completely eliminated by the short time available and the great horizontal distances that would have had to be traversed. Instead, a more-or-less direct vertical movement resulting from wind-driven mixing is indicated.

As shown in Table 1, there was close agreement between the strontium-90 concentrations of the 400- and 500-meter samples obtained in the Sargasso Sea region on July 13 and December 8, 1957, while significantly higher values were found in this region in July of 1958. This suggests that vertical transport takes place mostly during the winter, when surface water cools and wind velocities are high.

Measurements of Carbon Dioxide in the Atmosphere

The following material is based on a report by Charles D. Keeling, of the Scripps Institution of Oceanography, University of California. The more detailed account appeared in Tellus, *June 1960.*

A coordinated effort was made during the IGY and IGC-1959, by scientists of the Scripps Institution of Oceanography, the Woods Hole Oceanographic Institution, Lamont Geological Observatory, the University of Washington, and Texas Agricultral and Mechanical College, to determine the amount, distribution, and variations of carbon dioxide in the earth's atmosphere. (*Bulletins 16* and *20* present background information on the program and some early results.)

Although the CO_2 content of the atmosphere is comparatively small, it has an important influence on world climate. Ultraviolet and infra-red radiations from the sun are mostly absorbed in the earth's atmosphere—ultraviolet by oxygen at high levels, and infrared by CO_2 and water vapor at low levels. Most visible radiations, however, penetrate to the surface of the earth, where they are mainly reflected back to the atmosphere if they fall on snow or ice, or mainly absorbed if they fall on land or water. The visible radiations falling on land or water are heated in the process of absorption and are then re-radiated as infrared radiation, which is, in turn, partially absorbed in the lower atmosphere by CO_2 and water vapor, thus warming the air. This is the so-called "greenhouse effect," and one aim of the IGY program has been to attempt to ascertain whether man, in burning increasing quantities of fossil fuels (coal, oil, etc.), is causing this greenhouse effect to become intensified, with resulting long-range climatic changes.

It was found prior to the IGY that the content of CO_2 in the atmosphere, in contrast to oxygen, nitrogen, and the rare gases, is significantly variable. Later data has indicated that the variability is smaller and more systematic than previously believed.

This report presents preliminary results of investigations of atmospheric CO_2, carried out as part of the IGY and IGC-59 program. These studies show a systematic variation in the concentration of CO_2 with season and latitude in the Northern Hemisphere, but a small, steady increase in concentration in Antarctica.

Figure 6 shows the locations of CO_2 recording stations and the tracks of oceanographic research cruises and aircraft flights on which measurements were made during

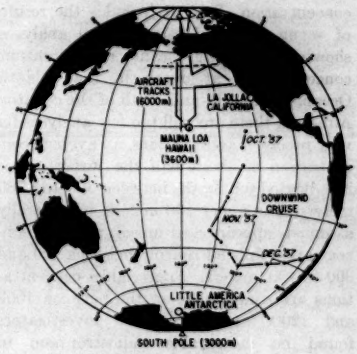

Fig. 6. *IGY-IGC Stations and Ship and Aircraft Tracks for Sampling of Atmospheric CO_2. Circles denote continuous-recording stations; triangles are those on Arctic Ocean drifting stations and at IGY South Pole Station. Elevations are given in meters for locations more than 100 meters above sea level; dotted line indicates approximate mean position of limiting temperature isotherm used to separate aircraft data into groups associated with higher and lower air temperature.*

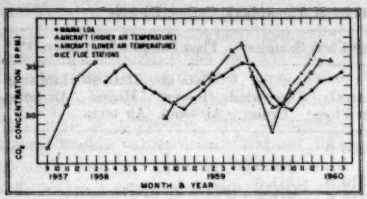

Fig. 7. *Variation in Concentration of Atmospheric CO_2 in the Northern Hemisphere, 1957–1960.*

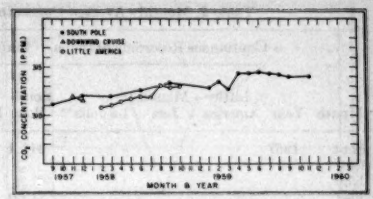

Fig. 8. *Variation in Concentration of Atmospheric CO_2 in the Southern Hemisphere, 1957–1960.*

the IGY-IGC under the direction of the Scripps Institution of Oceanography. US Weather Bureau personnel carried out sampling at the IGY Little America and Amundsen-Scott South Pole stations in Antarctica, at Mauna Loa Observatory in Hawaii, and at IGY Drifting Stations Alpha and Bravo, in the Arctic Ocean. C. E. Williams and J. C. Pales, of the Weather Bureau, operated the continuous-recording instruments at Little America and Mauna Loa, respectively, and reduced data to preliminary tabular form. The 55th Weather Reconnaissance Squadron of the US Air Force collected samples from aircraft; Maj. G. T. McClelland, Maj. B. M. Rose, Lt. R. E. Nagle, Lt. H. T. Fukuda, and Capt. J. D. Sharp were especially instrumental in planning and executing this work. N. W. Rakestraw and Lee Waterman collected samples during the Downwind Expedition, conducted by Scripps in the Southeast Pacific in the fall and winter of 1957–58 (see *Bulletins 7* and *16*).

Procedure

Three gas analyzers equipped with strip-chart recorders were employed during the IGY and IGC-59 to measure continuously the concentration of CO_2 at the stations in Antarctica, Hawaii, and California. A fourth analyzer was used in the laboratory to analyze samples of air collected in glass flasks at various locations. These analysers provide direct comparisons between the partial pressure of CO_2 in air (that part of total atmospheric pressure exerted by carbon dioxide) and that in prepared mixtures of CO_2 in nitrogen gas.

The relative accuracy of the data presented here is approximately ± 0.3 parts per million by volume. The uncertainty in the absolute values is considerably larger, however, since only a preliminary calibration of the reference mixtures has been made. When an accurate calibration is completed, the absolute accuracy is expected to approach ± 0.1 ppm. Monthly averages of the data from the continuously recording stations and from collections in flasks are presented numerically in Table 1 and plotted in Figures 7 and 8.

Results

Local contamination was found in the vicinity of all three continuous-recording stations. At Little America Station, it was evidently caused solely by combustion of fuel in the immediate vicinity of the station. It could be readily spotted from the significant fluctuations in the otherwise steady trace of the recorder pen and was eliminated from consideration in the initial reading of the charts.

At Mauna Loa Observatory, a less prominent variability was found in approximately half the records. This is attributed to release of CO_2 by nearby volcanic vents; to combustion associated with agricultural, industrial, and domestic activities on the

Table 2. Monthly Average Concentrations of Atmospheric Carbon Dioxide*

		Continuous Recording Stations			Surface Flask Samples			Flask Samples from Aircraft***		
Month	Year	Little America	Mauna Loa	La Jolla**	South Pole	Arctic Ice Floes	Downwind Cruise	Data at Lower Air temp.	Data at Higher Air temp.	Limiting Air temp. (°C.)
Sept	1957				311.1	306.5				
Oct							310.9**			
Nov						310.8	311.9			
Dec					312.0	313.6	311.6			
Jan	1958									
Feb		310.8								
Mar		311.0	313.4		311.9	315.5				
Apr		311.4	314.4	314.3					314.9**	−27
May		311.7	315.1	315.3						
Jun		311.9			312.5				314.9**	−21
Jul		311.8	312.9	311.1						
Aug		313.0	312.3	308.4						
Sept		312.9	311.6	308.7	313.3			308.3**	309.6	−18
Oct		313.0		310.8				312.8**	311.2	−27
Nov			310.6	313.2						
Dec			311.6	314.3						
Jan	1959		312.5	314.9	312.8				313.2	−36
Feb			313.5	314.4	313.4				314.1	−36
Mar			314.0	315.4	312.7					
Apr			314.7	315.0	314.3			316.6**	316.6	−27
May			315.3	315.0	314.3				317.3	−24
Jun			315.2	315.2	314.4			314.3	314.1	−21
Jul			313.5	311.5	314.2					
Aug			311.9	308.1	314.2			308.1	310.7	−18
Sept			311.1	308.7	314.0			311.0	311.1	−27
Oct			310.5	312.1				313.0	312.1	−27
Nov			311.8	313.7	313.9			314.2	313.2	−36
Dec			312.5	313.5				315.6	314.3	−36
Jan	1960		313.4	314.7				317.6	315.6	−36
Feb			313.7	315.4					315.6	−36
Mar			314.4	314.7						

* In ppm of dry air by volume

** Data not shown in Figures 2 or 3

*** Data separated into two groups based on temperature of the air at point of sampling. Limiting air temperature refers to the temperature separating the lower air-temperature group from the higher. It was chosen so that, for each sampling period, the boundary between warmer and colder air lies at approximately 50° N (see Fig. 7).

island; and to a lower concentration of CO_2 in air transported to the station by upslope winds. The values reported here are averages of data for periods of downslope winds or strong lateral winds, when the concentration remained nearly constant for several hours or more.

At La Jolla, California, the concentration

was found to be highly variable. Highest concentrations occurred when light winds blew from the north (from the direction of Los Angeles); concentrations were lowest when the wind was from the west or southwest and of moderate force or greater. Lowest weekly values usually did not differ by more than ±1 ppm during any month and, within a range of 2 ppm, agreed with values obtained by aircraft in the northern Pacific Ocean. Monthly averages of these data, which presumably indicate nearly uncontaminated air, are cited in Table 1.

Data for air collected in flasks from aircraft flying at 5 to 6 kilometers above the Pacific and Arctic Oceans and from surface stations at the South Pole and on Arctic ice floes show a high degree of regularity.

A clearly defined seasonal trend in concentration is found at all locations in the Northern Hemisphere. The annual range of concentration becomes greater from south to north and the month of minimum concentration occurs earlier. When the aircraft samples are separated into two groups based on air temperature at the point of sampling (Table 2), values for the high-latitude, or polar, air are seen to have a greater seasonal range than comparable values for air of the temperate zone. In contrast, data for the Southern Hemisphere do not indicate any seasonal variation. Data obtained on the Downwind Cruise in November and December 1957 suggest that the concentrations observed over Antarctica prevail at all southern latitudes of the Pacific Ocean.

The seasonal trend in concentration observed in the Northern Hemisphere (Fig. 9) may result from the activity of land plants. In the temperate zone, maximum concentrations have been found to occur in spring, at the outset of the growing season for plants, and minimum concentrations occur in the fall, approximately at the end of the growing season. The absence of a seasonal trend in the Southern Hemisphere may then be a result of the smaller area covered by growing plants at temperate and polar

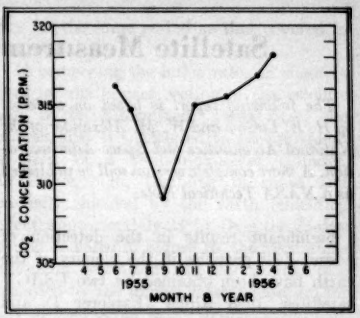

Fig. 9. *Variations in Concentration of Atmospheric CO_2. (Based on data by C. D. Keeling for various locations near the Pacific Coast of the United States.)*

latitudes in the Southern Hemisphere than in the Northern Hemisphere.

Where data extend beyond one year, averages for the second year are higher than for the first year. At the South Pole, where the longest record exists, the concentration has increased at the rate of about 1.3 ppm per year. Over the northern Pacific Ocean the increase appears to be approximately 1.0 ppm per year. Since measurements are still in progress, more reliable estimates of annual increase should be available in the future.

At the South Pole, the observed rate of increase is nearly that to be expected from the combustion of fossil fuel (1.4 ppm), if no removal from the atmosphere takes place. This agreement in the observed and expected rates of increase suggests that the oceans have been without effect in reducing the annual increase in concentration resulting from the combustion of fossil fuel. However, since the seasonal variation in concentration observed in the Northern Hemisphere is several times larger than the annual increase, it is also possible that a small change in the factors producing this seasonal variation may also have produced an annual change counteracting any oceanic effect.

Satellite Measurements of Cosmic Dust

The following report is based on material by H. E. LaGow and W. M. Alexander of the National Aeronautics and Space Administration. A more complete version will be published as a NASA Technical Note.

Significant results in the detection of cosmic-dust particles in the vicinity of the earth have been obtained by two US-IGY satellites, 1958 Alpha (Explorer I) and 1959 Eta (Vanguard III). This report deals primarily with the data from 1959 Eta (see *Bulletin No. 28*), comparing them with the earlier findings.

Technique and Instrumentation

Although several environmental sensors were carried on 1959 Eta, preliminary results are ready at this time only for the sensor measuring micrometeoroid impacts. The experimental apparatus consisted of a microphone-impact-counter system utilizing four piezo-electric transducers attached to the metallic skin of the satellite. A collision between the sensitive portion of the satellite surface and a dust particle produced a piezo-electric signal from the microphone system. The electric pulse resulting from an impact was suitably amplified and recorded in a three-digit decimal counter.

Each counter had as its most essential element a "rectangular-loop" type of magnetic core with a hole bored perpendicular to the coil axis. The configuration was named a "cyclops core." Rectangular-loop magnetic cores have the property of retaining any flux level to which they are set. Since the flux level of the cyclops core was changed only by the incoming counts, continuous monitoring of the signal was not necessary to determine the total number of impacts.

The telemetry system used had an output consisting of tone bursts separated by blank spaces. Information was contained in (a) the length of a tone burst, (b) the frequency of the burst, and (c) the length of time between one burst and the next. The counter information was presented in (b), as follows: the frequency of one tone burst was indicative of the units count, the frequency of a second tone burst indicated the tens count, and a third frequency indicated the hundreds count.

On 1959 Eta, the impactor sensor was calibrated as an impulse-measuring device, which measured a physical parameter of the impacting particle closely related to the particle's momentum. As more knowledge is obtained concerning hypervelocity impact phenomena, the exactness of the calibration of the acoustical devices used in dust particle sensors will be determined and sensitivity threshold levels of reported results can be adjusted, if necessary.

The threshold response of the sensor was determined by dropping very small glass spheres on the sensitive area of 1959 Eta's shell (about 60% of the surface of the spherical portion of the satellite). The mass of these beads was 55 micrograms, ±8%, and their velocities were known to an accuracy of ±5%. Except for an area of between one and two square inches centered over each microphone, the threshold sensitivity of the total sensitive surface varied between 0.9×10^{-2} and 1.2×10^{-3} dyne-secs. A one-inch-diameter circular disc was mounted over each microphone sensor; thus, for approximately 95% of the sensitive skin, the threshold sensitivity was as determined. The physical dimensions of the surface sensitive to dust-particle collisions was approximately four-tenths of a square meter.

Results

The data that has been reduced represents, primarily, one counter-reading per day.

Because there is an interaction between the magnetometer also carried aboard 1959 Eta and the microphone instrumentation for the micrometeorite experiment, a detailed study of all of the telemetry records must be made before final analysis of the data is complete.

The magnetic-field experiment required a command function from the ground stations, which added a count to the digital counter system on some of the interrogations. All of the satellite interrogations for magnetic-field data occurred when telemetry information was also being received; false counts entered in the counter were monitored and will be subtracted from the real counts. From the data reduced at this time, the average number of false counts per interrogation was determined, and a check was obtained by comparison with three periods during the satellite's lifetime when no interrogations were made.

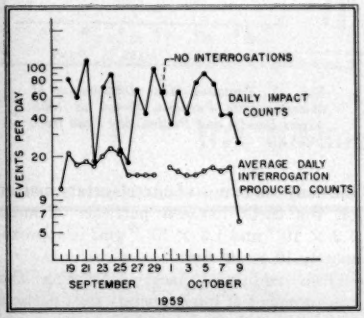

Fig. 10. *Preliminary Counts of Daily Impacts and Average Daily Counts Produced by Interrogations for the Period September 18–October 9, 1959.*

The total daily impact rate and the average daily false pulses due to the interrogations for the period September 18 to October 9, 1959, are shown in Figure 10. Figure 11 shows the corrected impact rate (average daily interrogation pulses subtracted from the total daily count) and the influx rate in impacts per square meter per day for the same period as that covered in Figure 10.

In computing the influx rate, an effective area for the impact section of the satellite had to be determined. Tentatively, the impact area is considered to be equivalent to that of a 20-inch-diameter cylinder, 10 inches high, tumbling in space and partially shielded by the earth (shielding effect, approximately 25%). Over the 22-day period depicted in Figure 10, the maximum-minimum variation of any count rate recorded by the impact instrumentation for any 24-hour period is less than a factor of 10.

One of the three periods during the lifetime of the satellite when no interrogations of the magnetometer experiment occurred was September 30, 1959. Sixty-five impacts on the sensitive area of the satellite were recorded during this 24-hour period. The average count per day for the above 22-day period, after interrogation counts were subtracted, was 45. Thus, the count recorded during the interrogation-quiet period was either higher than normal, or the average number of false pulses being used at this time is too high. It is expected that this

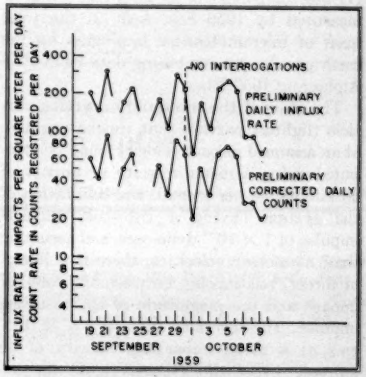

Fig. 11. *Preliminary Corrected Daily Impact Counts and Preliminary Daily Influx Rate, September 18–October 9, 1959.*

slight ambiguity will be practically eliminated when the complete data records are available.

The influx rate of particles per square meter per day (Fig. 11) ranged from 67 to 300. Figure 4 shows that the daily count rate varied by a factor of approximately 4½. It is felt that the measurement definitely indicates an average influx rate of at least 150 impacts/m²/day. The rate for the interrogation-quiet day was 210 impacts/m²/day.

Discussion

A tentative estimate of the number and mass of interplanetary particles striking the earth per day can be made using the data from 1959 Eta. This is done in terms of (1) the component of interplanetary matter measured by 1959 Eta, and (2) the total mass of micrometeorites impinging on the earth per day by combining data from 1958 Alpha and 1959 Eta.

The mass of the threshold impacting particle (lightest particle that can be counted, at an assumed impact velocity) may be computed using a mean velocity of impact of 30 kilometers per second, the calibration of the system having a threshold impact-impulse of 1×10^{-2} dyne-secs, and assuming that, at meteor velocities, there is a linear, or direct, relationship between the force of impact and the magnitude of the resulting impulse. The threshold mass is 3.3×10^{-9} gms at a mean impacting velocity of 30 km/sec. Using the average figure for the influx rate over the 22-day period and assuming, at the moment, that a significant number of meteoric particles are not in orbit around the earth, the mass influx per day on the earth of this component of interplanetary matter is 6×10^{2} tons.

An estimate of the amount of interplanetary matter falling on the earth each day can be obtained from two independent measurements, made by 1958 Alpha and 1959 Eta, which used the same type of sensors and calibration techniques. The threshold impact-impulse sensitivity of 1958 Alpha was 2.5×10^{-3} dyne-secs. The corresponding threshold mass sensitivity was 8×10^{-10} gms at a mean impact velocity of 30 km/sec. If it is assumed that the measurements by both satellites are valid dust-particle measurements, then, by extending the mass distribution curve defined by these measurements (Fig. 12),

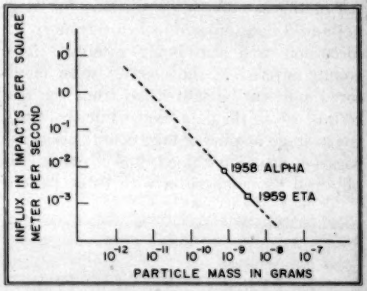

Fig. 12. *Tentative Mass Distribution of Micrometeorite Particles, Based on 1958 Alpha Results and Preliminary Data from 1959 Eta.*

the daily influx rate of interplanetary matter on the earth between particles of mass 1.2×10^{-8} and 1.2×10^{-10} gms is approximately 10×10^{3} tons.

Two additional facts concerning the measurement of interplanetary dust-particle influx by 1959 Eta should be noted. First, the number of actual events counted is the largest yet reported. The total count of impacts for the first 22 days is approximately 1000 (false pulses subtracted), compared with 153 for 1958 Alpha. Second, the area-time product for the lifetime of 1959 Eta was greater than 3×10^{10} cm²-secs, compared with an area-time product of 1.8×10^{8} cm²-secs for the earlier satellite.

Satellite 1958 Delta (Sputnick III) had sensors for direct measurement of particle influx. No clear indication of the total number of events or the area-time product has been published to date. However, the

average influx rate has been reported as 1.7×10^{-3} impacts/m^2/sec, with a threshold sensitivity of 10^{-9} gms, assuming a mean velocity of the meteor particles of 40 km/sec. Thus, considering the reported influx rates, and the corresponding mass threshold sensitivities of the sensors, the three satellite findings report an influx rate between 1×10^{-3} and 8.4×10^{-3} impacts/m^2/sec for mass threshold sensitivities ranging between 3.3×10^{-9} and 8×10^{-10} gms.

A brief comparison of the influx rate obtained by direct measurement techniques on 1959 Eta with the data obtained from various indirect measurement methods can be made. The indirect measurement methods can be classified in two main categories: (1) data obtained by visual and radar observations, and (2) data from considerations of zodiacal light.

Data from the first category contains influx information concerning particles down to a mass of approximately 10^{-5} gms. Various zodiacal-light computations consider particles with diameters from 10 to 300 microns. The data from the various methods in the first category are consistent with each other within a factor of 10. By extrapolating these data to the mass threshold of 1959 Eta, the average influx rate as determined by 1959 Eta is between 100 and 1000 times greater than the data from category one. The different zodiacal-light considerations are consistent with each other within approximately a factor of 100. In comparing these data with those of 1959 Eta, the result varies from an influx rate similar to that of the satellite findings to an influx rate 100 times smaller than that of the satellite measurements.

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IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs. The Bulletin *also reports on international programs in geophysics and space science that have grown out of the IGY, and on their results.*

Status of United States Scientific Programs in the Antarctic

The following material was prepared by Albert P. Crary, of the National Science Foundation. Dr. Crary is NSF's Chief Scientist for the US Antarctic Research Program. During the IGY, Dr. Crary was Deputy Chief Scientist of the US Antarctic Program, Scientific Station Leader at Little America IGY Station for two and a half years, and leader of the two major IGY oversnow traverses from Little America Station.

Since the close of the IGY, coordination and administration of the United States Antarctic Research Program has been the responsibility of the National Science Foundation. Prior to that time, development and supervision of US scientific programs in Antarctica were the responsibility of the National Academy of Sciences and its US National Committee for the IGY. Financial support was received by the Academy from the Congress through the National Science Foundation, and logistic support was afforded by the US Navy.

Even before the end of the observational phase of the IGY, in December 1958, it had become evident that world-wide, cooperative research in geophysics had proved more valuable than the most optimistic forecasts, and consequently would benefit from continued international study and cooperation. Accordingly, in 1957 and 1958, the IGY parent body, the International Council of Scientific Unions (ICSU), established several groups to coordinate the long-range post-IGY effort; among these was the Special Committee for Antarctic Research (SCAR), established in February 1958.

Following the pattern of the IGY, the National Academy of Sciences established in this country the Committee on Polar Research to cooperate with SCAR in coordinating international programs in Antarctica and to advise US agencies on the formulation of the post-IGY US Antarctic program. Laurence M. Gould, President of Carleton College, is the Chairman of CPR; Dr. Gould was also the Chairman of the USNC-IGY Antarctic Committee.

The US Antarctic Research Program now consists of research conducted at six Antarctic installations, augmented by oversnow traverses and field parties in selected areas, as well as in laboratories and research centers in the US. The Byrd, South Pole, and McMurdo Stations are wholly US stations. At Hallett Station the program is a cooperative New Zealand-US effort, as it was throughout the IGY. Since the end of the IGY, the Ellsworth and Wilkes Station programs have been conducted cooperatively with Argentina and Australia, respectively. (See Figure 1.)

Within NSF, Thomas O. Jones serves as Antarctic Program Director. Scientific projects of the US Antarctic Research Program are arranged by the National Science Foundation in consultation with the Committee on Polar Research. Government agencies with interests in the Antarctic are represented through the Interdepartmental Committee on Antarctic Research, a second advisory group assisting the Foundation. The US Naval Support Force, Antarctica, commanded by Admiral David Tyree, provides the operating personnel for the Byrd, Hallett, and South Pole Stations and for the Naval Air Facility at McMurdo Sound, and also furnishes logistic support generally.

The US scientific programs in Antarctica have been maintained at approximately the same man-power level as during the IGY. Although there has been a reduction in the number of stations wholly operated by this country, additional emphasis is being placed on biology and geology, which were not major fields of study during the IGY, and a scientific staff has been added at McMurdo. A major change in the mode of scientific operation has been the limiting of wintering-over personnel, for the most part, to scientists in upper-atmosphere disciplines and in meteorology. Summer personnel of the glaciological, biological, and geological programs can now fly to the continent in October or November and complete their work by January or February. The numerical breakdown of US scientific personnel for the post-IGY studies is shown in Table 1.

Table 1. Numerical Breakdown of US Antarctic Personnel for 1959 and 1960

	1959 Wintering-over Team	1959–60 Summer Team	1960 Wintering-over Team
Administration	0	7	0
Biology	3	11	2
Cartography	1	2	0
Geology	0	13	0
Glaciology	3	9	2
Meteorology	13	1	17
Oceanography	0	4	2
Psychology	0	1	0
Traverse Seismology & Gravity	2	2	1
Traverse Engineering	2	0	2
Upper Atmospheric Physics	8	1	9
Total	32	51	35

Biological and Medical Sciences

The biological and medical sciences were not included in the official IGY Antarctic Programs; however, workers in these fields were encouraged to take advantage of the unique opportunities afforded by the remote and severe Antarctic environment, and some valuable work was done. Beginning with the 1958–59 austral summer, when six independent life-sciences programs were undertaken, the increase in work in these fields has been rapid; 13 life-sciences programs were conducted in the 1959–60 Antarctic summer. Three of these included wintering-over scientists.

At Wilkes Station, a University of Wisconsin investigator has conducted studies since early 1959 and will remain until early 1961. This program deals with the sexual and parental behavior and the orientation mechanisms of the Adélie penguin. Before migration of the penguins in February 1959, near the end of the 1958–59 summer season, 500 were banded, a census was taken, and observations were made of their weights, moulting habits, general behavior, and history. Studies were also made of the skua and other birds, and of seals.

During the 1959–60 summer, the complete Adélie reproduction cycle was studied: the penguins first arrived in mid-October, the first chicks were seen in mid-December, and the last Adélies were seen on February 3. Several thousand were banded and the program of behavior studies was successfully carried out. Other avian studies were made, when possible, on the skuas and petrels near the station and at other sites in the Windmill Island Group.

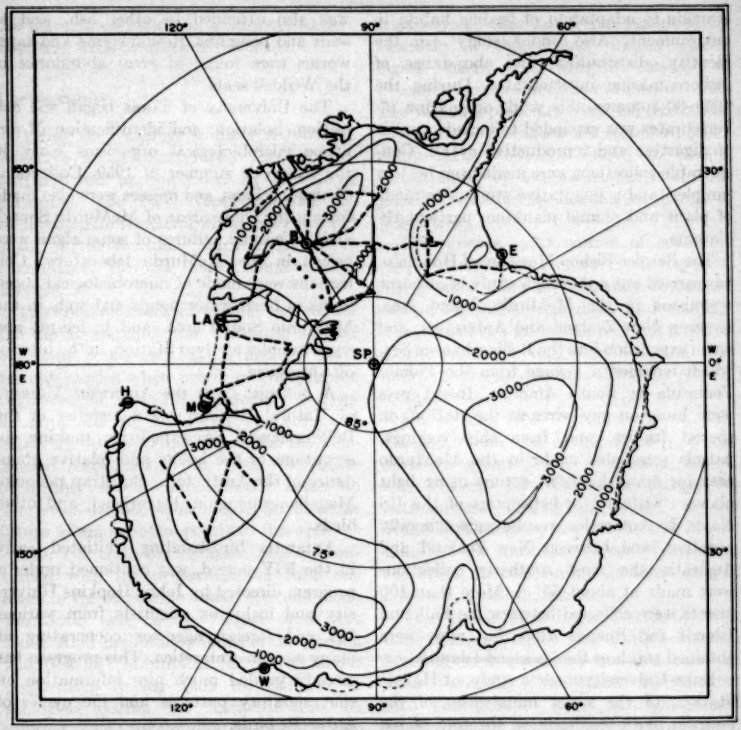

Fig. 1. *Approximate Thickness of the Antartic Ice Cap. Thickness shown in 1000-meter intervals; heavy dashed lines are routes of US oversnow traverses thus far; light dashed lines indicate approximate borders of shelf ice. US and cooperative scientific stations are indicated as follows: SP—South Pole, LA—Little America, B—Byrd, M—McMurdo Sound, W—Wilkes, E—Ellsworth, and H—Hallett.*

At McMurdo Station, a complete biological and medical-science laboratory was established in the 1958–59 season by the Arctic Institute of North America (AINA). The laboratory is now being monitored, supplied, and operated by Stanford University. With this laboratory as a focal point, a great many diverse projects have been carried out in the McMurdo Sound area.

A University of Tennessee program to study land invertebrates began in October 1958 and continued until March 1960. Collections were made in a large area around McMurdo Sound and near Hallett Station. The study also included an attempt to determine how these invertebrates adapt themselves to climatic conditions, through a detailed microclimatic study near the surface.

A Stanford University biological program deals with size, age, growth, and metabolic rates of Antarctic fish. Particular reference

is made to adaptation of feeding habits to environment. Also under study are the identity, distribution, and abundance of inshore marine invertebrates. During the 1959–60 summer, this work on marine invertebrates was expanded to include studies of digestive and reproductive cycles. Considerable collections were made from bottom samples, and a quantative study was made of plant and animal plankton, particularly diatoms.

The Bernice Bishop Museum, of Honolulu, has carried out a thorough study of airborne organisms in the McMurdo Sound area, between New Zealand and Antarctica, and on an expedition into the Bellingshausen Sea, which included a voyage from the Palmer Peninsula to South America. Insect nets were hung on guy wires at the station, on special frames, and from ship riggings; patrols were also made in the McMurdo area for many hours at a time using light planes ("Otters") or helicopters of the US Navy. In Antarctica, results were generally negative, and between New Zealand and Australia the most southerly collections were made at about 55° S. More than 100 insects were collected between the Falkland Islands and Buenos Aires, but none were obtained south of the Falkland Islands.

Duke University made a study, at Hallett Station, of the water metabolism of the penguin, with emphasis on the role of sea water and salt in the food. It was found that newly hatched chicks have a well-developed salt gland, which can function immediately after hatching, and that the capacity for excretion of salt increases during development. In a series of tests, it was noted that birds subjected to water loads did not respond by heavy diuresis.

The Virginia Fisheries Laboratories is studying the parasites of Antarctic vertebrates and invertebrates. During the 1959–60 summer, the studies centered mainly on parasites from the fish Trematomus, and many types of parasites—flukes, roundworms, tapeworms, and leeches—were found in the digestive tracts of this fish. The work was also extended to other fish, and to seals and penguins. Roundworms and tapeworms were found in great abundance in the Weddell seals.

The University of Texas began the collection, isolation, and identification of airborne microbiological organisms early in the Antarctic summer of 1959. Collections of algae, lichens, and mosses were also made from many shore areas of McMurdo Sound, and monoxenic cultures of some algae were grown in the McMurdo laboratory. Collections were made of microbiological specimans in fresh water ponds and soils in the McMurdo Sound area, and in ice-pit and snow samples at Byrd Station, in the interior of Antarctica.

A biologist from the American Museum of Natural History was a member of the Bellingshausen Sea expedition, making observations of the habits and relative abundance of the Arctic tern, chinstrap penguin, Magellanic penguin, loggerhead, and other birds.

Antarctic bird-banding, initiated early in the IGY period, was continued under a program directed by Johns Hopkins University and including scientists from various US and foreign agencies cooperating at many sites in Antarctica. This program has already yielded much new information on the migratory patterns and life cycles of Antarctic birds.

Medical work continues on upper-respiratory-tract infections prevalent in Antarctic personnel following isolation; this work was begun in 1959. Through the cooperation of US Navy medical doctors, blood sera and swabs were collected from volunteers wintering over in Antarctica for study of viruses and bacteria. The epidemiological information obtained are of considerable interest with respect to furthering knowledge of viruses of the common cold.

Observations were carried out on the group behavior of an Antarctic oversnow traverse party by a psychologist from George Washington University. Considerable insight was obtained on the effects of stresses of

the traverse operation on authority, leadership, and work-production problems.

Cartography

During the Antarctic summer of 1959–60, extensive aerial photography for mapping purposes was accomplished by US Navy personnel. The P2V Neptune plane, instrumented for trimetrogon cameras, covered areas of the Sentinel, Horlick, Executive Committee, Victoria, and Commonwealth Ranges.

The establishment of ground control for the aerial mapping was continued on the oversnow traverses (Fig. 1) and by other ground parties when possible. Topographic engineers of the US Geological Survey accompanied the Byrd and Victoria Land traverses. A third engineer, on the Bellingshausen expedition, was able to locate accurately several exposed-rock areas on Thurston Island, which can be used as future ground-control points in this area.

The U.S.G.S. Cartographic Section continued with the preparation of Antarctic maps in the McMurdo Sound area and along the Budd and Sabina Coasts of Wilkes Land. Also, preliminary maps of the Horlick and Sentinel Mountains have been under preparation during 1960 for the use of geologists during the Antarctic 1960–61 summer. The Cartographic Section has also printed thousands of photographs of various Antarctic areas for the use of scientists in the preparation of their final reports.

The American Geographical Society has continued to maintain a current map of Antarctica on a 1:3,000,000 scale, using US and foreign geographic information as it is made available.

Geology

Though not an IGY discipline, much preliminary geological information was obtained by personnel from other disciplines, mainly on the oversnow traverses.

The bedrock geology of the Windmill Islands in Wilkes Land was examined by members of the Wilkes Station glaciological team. The bedrock consists of Precambrian metamorphic and igneous rocks. The metamorphics are very old rocks and appear to be remnants of a folded volcanic-sedimentary sequence, altered to biotite, hornblende, or magnetite-garnetiferous gneisses, containing intercalated bands of pegmatite.

The igneous rocks consist of coarse to porphyritic diorite, quartz diorite, syenite, and granite. They are generally featureless except for some basic dikes and faulting. The ages of two gneiss samples and a quartz diorite from this region are 950 and 1120 million years, as determined by the A^{40}/K^{40} method.

During the 1957–58 traverse from Ellsworth Station, the Dufek Massif, in the northern group of the Pensacola Range, was visited. The Pensacola Range lies between the Shackleton Range, in the Weddell Sea region, and the Horlick Mountains, at the southeast corner of the Ross Ice Shelf; its relationship to these ranges, however, is still indistinct.

The Dufek Massif was found to be a basic igneous complex with nearly horizontal layering and banding. On the basis of color, the rocks of the Massif were divided into two groups: (1) a medium-grained diorite, which grades locally into gabbro, anorthosite, or a gneissic-looking rock belonging to the gabbro-norite clan; and (2) a group of rocks resembling syenites or leucodiorites but petrographically also classified as gabbro-norite.

The Sentinel Mountains were very briefly visited by the Byrd traverse party of 1957–58 and by an airlifted party in 1959–60. Low-grade, folded metamorphic rocks were found in the western foothills of the range. The main range, as determined by field observations and study of aerial photographs, consists of strongly folded strata with an expected north to northwest trend and probably cut by intrusive rocks. The Sentinels are probably a typical linear

folded mountain system but their age and relation to the "Antarctic Andes" is unknown.

Rocks from the central range of the Horlick Mountains, visited by members of the Byrd traverse party of 1958–59, are relatively undisturbed and are elevated as block-type mountains. Lying unconformably on the exposed "basement" complex are fossiliferous Lower Devonian marine strata. The overlying succession of sedimentary rocks, assigned to the Beacon group, consists of graywackes, followed by sandstones, siltstones, shales, and coal seams. In the upper part, plant leaves (*Glossopteris*) and fossil wood are present. Major block-faulting and tilting, with vertical displacement of 2000 to 3000 meters, has created a steep northern escarpment which may be an extension or continuation of the escarpments of the Queen Maud and Royal Society Ranges.

During the traverse from Ellsworth to Byrd Station in 1958–59, specimens were collected from a nunatak at 81° 53′ S, 89° 20′ W. The specimens consist of two similar types of metamorphic rocks, one of which showed evidence of contact with an igneous rock; two samples of granitic rock; and a rock collected from talus. All of the specimens are unlike any rocks of the Beacon group. The metamorphic specimens may have been Precambrian or younger sedimentary rocks later intruded by granitics.

The Executive Committee Range, visited in early 1959 by a traverse from Byrd Station, consists of rocks of volcanic origin. The high peaks are almost exclusively made up of a variety of basalt, with olivine basalt predominant in the specimens collected.

During the 1959–60 Byrd traverse, investigations of the Toney Range showed it to be mostly volcanic, with basalt and basic agglomerates. Volcanic rocks lay unconformably over diorites on an uncharted nunatak at 76° S, 124° W. Nunataks at the south end of the Edsel Ford Range were also visited, and granite of probably batholithic proportions were noted intruding a metagraywacke sequence.

On the Bellingshausen Sea expedition, geologists from the University of Minnesota and the U.S.G.S. visited various sites on Thurston Island. The bedrock examined there is hornblende-bearing diorite gneiss cut by dikes. This series of rock has a northeast-southwest trend. No definite age determination has been made, but the rocks appear to be Andean or older. One small basaltic pebble gave evidence of volcanic origin.

The geologists also landed on different parts of Peter I Island, confirming that it is a basaltic volcanic island. Two wave-cut beaches were noted—one below sea level and the other at elevations of about 200 to 250 meters.

South Victoria Land was studied during the past two Antarctic summers by geologists from the U.S.G.S., Tufts College, and the University of Kansas. Programs of the U.S.G.S. included study of the pre-Beacon batholith and the stratigraphy of part of the Beacon sandstone. Results indicate that movement along the great Antarctic Horst may have begun in the early Precambrian.

Geologists from Tufts College studied Wright Dry Valley, elevated beaches in the vicinity, and the geomorphology of the Marble Point area of McMurdo Sound.

University of Kansas scientists studied the thermoluminescence of Antarctic limestones in an effort to determine their past thermal history. Preliminary results give an approximate minimum age for Antarctic glaciation of 170,000 years.

In the course of traverse operations in West Antarctica, a major sub-ice channel was located between the Ross and Bellingshausen Seas. A combination of magnetic, geologic, and seismic evidence indicated that this channel represents a fundamental division between geologic provinces. Gravity studies show West Antarctica to be in approximate isostatic equilibrium. They also show that the crust is continental in character, with the base of the crust at a

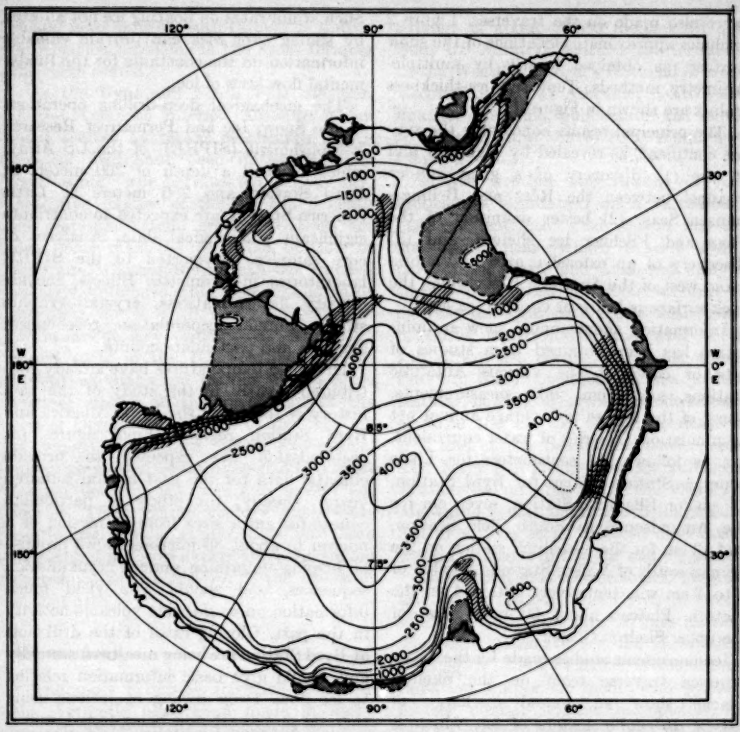

Fig. 2. *Approximate Elevations of the Antarctic Ice-Cap Surface. Elevations shown in 500-meter contour intervals; stipple pattern represents approximate known extent of ice shelves; line pattern represents regions in which there is much exposed land.*

relatively high average elevation. An extensive program of analysis of seismic, gravity, and magnetic traverse data is being conducted at the University of Wisconsin.

Glaciology

Glaciological studies in Antarctica since 1957 included the oversnow traverse work in inland regions, station glaciology, deep drilling, ice-deformation studies, and a general Ross Ice Shelf movement study.

Traverses since the beginning of IGY have covered more than 16,500 kilometers (10,250 miles). Figure 1 shows the various US traverse routes. The main glaciological information sought on the traverses was elevation of the ice surface; thickness of the ice, as determined by seismic, gravity, and magnetic observations; annual snow accumulation; and near-surface snow and firn properties. Studies in other disciplines

were also made on the traverses. Figure 2 includes approximate elevations of the snow surface, as obtained mostly by multiple-altimetry methods. Tentative ice-thickness values are shown in Figure 1.

The principal results concerning the sub-ice continent, as revealed by Figures 1 and 2, are (1) discovery of a great sub-ice channel between the Ross and Bellingshausen Seas, (2) better definition of the Ross and Filchner ice shelves, and (3) discovery of an extensive area in Victoria Land west of the Antarctic Horst where the rock surface is below or close to sea level.

Information about annual snow accumulation has been obtained from studies of pits or cores at the various Antarctic stations, and from stake measurements. Some of the figures for average annual net accumulation, in terms of water equivalent, are as follows: 24 centimeters for Little America Station, 16 cm for Byrd Station, 18 cm for Ellsworth Station, seven cm for the Amundsen-Scott South Pole Station, and 13 cm for the "satellite" station on the ice cap south of Wilkes Station. A value of 2 to 4 cm was tentatively obtained on the Victoria Plateau about 60 miles west of the upper Skelton Glacier.

Ice-movement studies made by the Little America traverse team on the Skelton Glacier show an annual discharge of 791×10^6 cubic meters of ice, which is sufficient to account only for the accumulation in the upper névé fields of the Skelton Glacier. It thus appears that the Victoria Land Plateau does not contribute ice to the western part of the Ross Ice Shelf through gaps in the mountains along the Antarctic Horst.

Strain rates obtained on the Ross and Filchner Ice Shelves show that the creep of the ice (slow, continuous horizontal strain) is about one meter per kilometer per year, and is at a maximum in the direction perpendicular to that of absolute ice flow. In general, the ice creep obeys theoretical patterns determined from thickness, density profile, and temperature profile. Such strain rates on floating ice not affected by sliding over rock can provide valuable information on the constants for the fundamental flow laws of ice.

The mechanical deep-drilling operations of the Snow, Ice and Permafrost Research Establishment (SIPRE), of the US Army, which reached a depth of 300 meters at Byrd Station and 250 meters at Little America Station, are expected to contribute significant glaciological data. Analyses of core samples transported to the SIPRE laboratories in Wilmette, Illinois, include density determinations, crystallographic studies, annual accumulation, geochemical analysis, and particulate counts.

Drill-hole temperatures have already contributed greatly to the study of the past history of the ice in the Little America and Byrd Station regions. Final figures for accumulation are expected to provide climatic data for the past several hundred years. Already, the study of particulate counts for grain sizes from a fraction of a micron to about 80 microns shows promise of helping determine annual accumulation sequences, and should also yield much information on world-wide volcanic activity in the past. Closing rates of the drill hole at Byrd Station are being measured annually and should give basic information relating to ice flow. Deep-drilling operations using thermal probes are now being tested, and it is hoped that this apparatus will be able to penetrate the entire thickness of the ice cap.

A program was begun in the summer of 1959–60 by the University of Michigan that may eventually provide information on absolute movement; differential movement, or creep; volume of ice discharge; and accumulation along the front of the Ross Ice Shelf from Little America to McMurdo Sound. Studies of ice deformation in the area north of Roosevelt Island, in the northeastern part of the Ross Ice Shelf, have yielded much information on the association of horizontal compressive stresses with firn folds and crevassing; these findings

should be of interest with respect to similar deformation problems in the rocks forming the earth's crust.

At the Byrd and South Pole Stations, in the Antarctic interior, absolute movement studies by means of accurate astronomical fixes have been initiated. These "star shots" will be repeated periodically, indicating motion of the ice cap beneath the stations. Annual gravity readings are also being made at the Pole Station to determine whether the ice cap has reached a steady state or is still either expanding or shrinking.

Glacial geology studies at McMurdo Sound early in the IGY outlined several Pleistocene glaciation periods in this area. Further studies in the lower part of the Taylor Dry Valley have led to identification of deposits laid down during four glacial advances as well as an inter-glacial deposit formed between the first and second advances. These glacial geology studies are continuing. Similar studies have also been carried out at the Wilkes Station and should contribute to the history of the ice sheet in that area.

Meteorology

The most extensive scientific efforts in the Antarctic have been made in meteorology. Data collections were the result of a joint effort by the US Weather Bureau and aerologists of the US Navy, and special observational programs as well as analysis of data have been accomplished by the Weather Bureau.

The main effort continues to be in the synoptic upper-air observations of temperature, pressure, humidity, and wind speed and direction, as observed twice daily with rawinsonde balloon flights. During 1959, 3812 rawinsonde balloon flights were made at all US and cooperative stations, totalling 87% of all scheduled flights. The average height of the balloon flights during 1959 was 21,500 meters, ranging from a winter average of about 18,000 meters to a summer average of about 24,500 meters. All data from US Antarctic stations are forwarded to the Weather Bureau's National Weather Records Center, at Asheville, North Carolina, for reduction, publication, and release to research units and to IGY World Data Centers.

Surface weather observations in Antarctica are maintained on a three-hourly basis. A "satellite" field station was also maintained near Wilkes Station during part of the year, and a second outlying station is planned for 1960 in order to increase the areal coverage of near-surface pressures, temperatures, and wind speeds and directions. During the flying season, the US Navy operated surface weather stations, making many rawinsonde releases, at Mile 160 on the Little America-Byrd trial and at the Beardmore Glacier camp. The Navy has also started an automatic-weather-station program in the vicinity of McMurdo Sound and in the Bellingshausen Sea area. The scope of these observations will be increased during the coming year.

Many additional meteorological programs are carried out at the Byrd, Ellsworth, Hallett, South Pole, and Wilkes Stations. The most extensive are the observations relating to energy-balance. Ground-based radiation studies are made with pyrheliometers, normal-incidence radiometers, and illuminometers. Beginning in April 1959 at Hallett Station, radio-metersonde equipment has been sent aloft several times a month to obtain vertical profiles of radiative heat transfer; this program has been extended to the South Pole and Byrd Stations.

Surface measurements of carbon dioxide were made in 1959 at the Ellsworth and South Pole Stations. Also at the Pole Station, US Weather Bureau Personnel operate Naval Research Laboratory equipment to measure radioactive fallout for the purpose of studying atmospheric motions.

In cooperation with the glaciological programs, meteorological observers at the South Pole, Byrd, and Wilkes Stations are measuring accumulation or ablation of snow,

or both, using a network of stakes. They are also measuring snow and ice temperatures with buried thermohms.

On the oversnow traverses, standard weather observations are made at regular intervals. Temperatures are also taken at a depth of 10 meters at all major stations on the traverses. It has already been demonstrated that 10-meter ice temperatures are very close to annual average near-surface air temperatures; hence, these measurements make it possible to obtain this important climatological data in remote areas without the need for permanent stations.

At the International Antarctic Analysis Center in Melbourne, Australia, a US Weather Bureau research meteorologist is assisting in the preparation of current weather charts at six constant-atmospheric-pressure levels from the surface to 300 millibars (about 26,000 feet), and of time cross-sections for selected stations south of 30° S. In addition to the analysis program, the staff at Melbourne also undertakes various research studies.

The US Weather Bureau has continued to maintain an Antarctic research group in Washington in accordance with its enormous data-collection program. The main research programs considered to date have concerned the horizontal transfer of energy, including net transfer of water vapor into the Antarctic continent; the distribution and variations of incoming and outgoing radiation; detailed studies of the sudden spring warming of the Antarctic stratosphere, and comparisons with Arctic conditions; studies of the ocean-atmosphere exchange of energy; and studies of atmosphere-icecap exchanges. A climatological study was also inaugurated in 1959 by the University of Wisconsin.

Oceanography

A very large amount of oceanographic data was collected during 1959 by personnel of the US Navy Hydrographic Office working on Task Force icebreakers. This data has included bathymetry, variation of water salinity and temperature with depth, shallow bottom samples, plankton hauls, etc. In 1959–60, oceanographic work included over 16,000 miles of sonic soundings, nearly 4000 miles of pack-ice reconnaissance, 7000 miles of continual surface temperatures, 1000 bathymetry lowerings, 43 ocean stations, three plankton hauls, and 15 bottom-core samples. Much of this work was done in the little-known Bellingshausen Sea area.

A limited amount of sub-Antarctic oceanographic work has been done by the research vessel *Vema*, of the Lamont Geological Observatory, Columbia University. These investigations concentrated on submarine geology, with the aid of numerous ocean-floor photographs, dredging, deep bottom cores (as much as 20 meters long), and seismic techniques. Past work of the *Vema* has been concentrated in the Scotia Sea area, but in early 1960 the ship cruised in the South Pacific between Australia and South America. The *Vema* is not able to cruise in ice-covered waters, however, and its activities are limited to Antarctic waters considerably north of the ice pack.

A shore-based oceanographic program was initiated in the summer of 1959–60 at McMurdo Station, thus continuing work done in 1959 by traverse-party members stationed at New Zealand's Scott Base. The main studies concern water temperatures, salinities, and currents, and details of ice conditions in McMurdo Sound. Tidal studies were made successfully during the IGY on both the Ross and Filchner Ice Shelves, over relatively deep water, by observation of gravity meter variations.

Seismology

At four US Antarctic stations, seismology equipment generally identical to that used during the IGY period is being employed. The equipment at the Byrd and South Pole Stations is operated under the direction of the US Coast and Geodetic Survey (USC&GS); at Hallett Station, the Lamont Geological Observatory directs the seismic

work; and at Wilkes Station it is directed by the California Institute of Technology. At Hallett and Wilkes Stations, the scientists operating the equipment are from New Zealand and Australia, respectively.

Information from these seismology stations is used in the world-wide earthquake epicenter program of the USC&GS; in the delineation of continental and oceanic crustal structure in the Antarctic; in the study of microseisms; and in the study of the propagation of "body" waves through the earth. It is expected that further studies of Antarctic crustal structure will soon be inaugurated at California Institute of Technology as a continuation of the earlier analysis of surface waves, which showed that continental structure in the south polar region may be limited to East Antarctica. Generally, it has been found that Antarctica is not a particularly active seismic region.

Upper-Atmospheric Physics

Collection of atmospheric-physics data in Antarctica continued during 1959 at approximately the same level as during the IGY. US scientists continued investigations at Byrd and South Pole Stations, while Argentine and Australian scientists conducted studies at Ellsworth and Wilkes Stations. At the joint NZ-US Hallett Station, New Zealand scientists continued their studies as during the IGY.

The aurora program consisted of three main parts: (1) visual observations directed by Cornell University, and (2) all-sky camera and (3) patrol spectrograph observations by the Geophysics Research Directorate of the Air Force Cambridge Research Center. The aurora studies generally cover the portion of the year from April to September, though at Wilkes, the northernmost station, observations were possible for some nights in early March and October.

Cloudy weather limited auroral observations by varying amounts. Thus, on the average, it was possible to conduct observations at all stations for about 60% of the total possible observing time. Wilkes Station had the highest number of cloudy days, limiting observations to about 38% of the total possible observing time, while at the South Pole Station it was possible to conduct observations 85% of the time.

Additional equipment for 1960 includes an airglow photometer and a riometer at Hallett Station, where a US aurora scientist is now working. Reduction of auroral data has been conducted according to international agreements.

Geomagnetic recordings in Antarctica are obtained by the USC&GS at the Byrd and South Pole Stations, while cooperative programs, using US equipment and scientists of other countries, are being carried out at Hallett, Ellsworth, and Wilkes Stations. Temporal variations of the magnetic-field vector are obtained with standard magnetographs at all stations, and rapid-run magnetographs are also in use at Byrd and Wilkes Stations.

The building originally constructed at Little America Station to make absolute magnetic-field measurements has been moved to the South Pole Station, where absolute values were obtained for the first time in 1959. At all of the Antarctic stations, absolute measurements are made periodically, usually once a week if conditions are quiet but only once a year at Hallett Station. At the Byrd Station, a proton-precession magnetometer will soon be in use to provide an absolute standard.

Vertical-incidence sweep-frequency ionosphere sounders furnished by the National Bureau of Standards are operated at the Byrd, South Pole, Ellsworth, Hallett, and Wilkes Stations. These sounders make 15 second sweeps through a frequency range of 1-15 mc/sec every 15 minutes, or on a more accelerated time schedule during special periods.

Radio-noise equipment has also been in operation at Byrd Station to obtain the average power level of radio noise at eight frequencies between 51 kc/sec and 20

mc/sec. This program has been only partially successful because of the high level of radio noise associated with station activities. It is planned to relocate this part of the scientific program at a greater distance from the station in the near future.

At Byrd and Ellsworth Stations, a program of whistler monitoring was conducted during 1959 using a loop antenna. The 15.5-kc pulse broadcast over station NSS, Washington, D. C., was also monitored at regular intervals. Whistlers have generally been at a maximum during the April-to-September period, and at peak periods of activity as many as 100 whistlers per minute have often been recorded. The NSS whistler-mode echoes are observed only during Antarctic winter months. Additional whistler-monitoring equipment is now in use at the South Pole Station.

Cosmic-ray studies were made only at Ellsworth Station during 1959. Both the neutron monitor for low-energy cosmic rays and the meson telescope for high-energy particles were used. Near the end of 1959, however, the meson-telescope observations were discontinued. During the 1959–60 summer, cosmic-ray neutron-monitor equipment was installed at McMurdo Station.

Analysis of upper-atmospheric-physics data progressed well, with the main concentration thus far mostly on descriptive aspects. The location of the southern auroral zone has now been fairly well defined, and "magnetic bays" and ionosphere variations shown in the records of various stations has been documented. In general, a surprising degree of agreement between auroral, magnetic, ionospheric, and other upper-atmosphere phenomena has been found, but only a few of the features have as yet been studied in detail.

From the cosmic-ray data obtained at Wilkes Station during the IGY, it appears that seasonal variations of primary cosmic-ray activity may be related to atmospheric conditions. Also the data indicates that all solar flares may result in cosmic-ray-intensity increases, although these would be subject to variations related to geographic distribution.

Scientist Exchange Program

During the IGY, exchange of scientists in Antarctica between the US and other nations associated with SCAR added considerably to coordination and cooperation between nations and increased mutual knowledge of the variety of scientific methods and equipments used by them.

Beginning late in 1959, a further exchange of scientists between the US and USSR was made and will continue until early 1961. At the USSR Mirny Station, a US seismologist from the California Institute of Technology is at persent carrying out gravity, magnetic, and seismic researches in the vicinity of the station; he will also participate in one of the USSR oversnow traverses during the Antarctic summer of 1960–61. A USSR glaciologist is conducting special studies at the US McMurdo Station and will participate in a US traverse to the South Pole in 1960–61.

A French glaciologist participated in the US Victoria Land traverse during the Antarctic summer of 1959–60. Since he had previously worked with the French traverse party south of Durville and Charcot Stations, he was thus enabled to extend his snow-accumulation and geochemical studies in the same general area.

The Echo Communications Satellite

The Echo I satellite, a large inflatable sphere designed to serve as a passive, high-altitude reflector for long-range communications signals, was launched by the United States at approximately 5:40 am EDT, Friday, August 12, 1960, from Cape Canaveral, Florida. About 20 minutes later, the satellite, designated 1960 Iota 1, was injected into a high, nearly circular orbit by the third-stage rocket of the new Delta vehicle used for the launch. The third-stage rocket casing, which is also in orbit, has been designated 1960 Iota 2.

Well in advance of the launching, the National Aeronautics and Space Administration (NASA), which directs Project Echo, requested the National Academy of Sciences to invite researchers in other countries to use the satellite for experiments of their own. Accordingly, the Academy's Space Science Board (SSB) relayed this invitation and detailed information on Project Echo to its international counterpart, the Committee on Space Research (COSPAR), for transmission to all COSPAR participants.

As soon as it had been ascertained that 1960 Iota 1 was in orbit, a message giving orbital information and other details was sent by SSB to COSPAR for distribution, and to SPACEWARN (which also functions as the World Warning Agency—AGIWARN—established during the IGY) for dissemination to the world scientific community generally. To assist experimenters in other countries, NASA is providing tracking data for distribution via SPACEWARN. Data obtained in the course of the Echo experiment will be forwarded to COSPAR and will also be deposited in the IGY World Data Centers.

Cooperating closely with NASA in the Echo experiment are the Bell Telephone Laboratories (BTL), the NASA Jet Propulsion Laboratory (JPL), and the Douglas Aircraft Company. BTL, under contract to NASA, is working together with JPL in a major phase of the experiment—transmitting communications signals from coast to coast by reflection from the satellite's surface. The Douglas Aircraft Company, under contract to NASA, designed and constructed the Delta launch vehicle and conducted the countdown. A large number of other private and public agencies also participated in the design and construction of the numerous rocket and satellite components and are taking part in the experiment and in tracking operations.

Orbital Data

Program plans for 1960 Iota 1 called for a circular orbit at a nominal altitude of 1000 statute miles. The orbit achieved has a perigee of about 945 miles and an apogee of about 1049 miles, nearly as intended. The satellite's velocity is approximately 15,973 mph at perigee and 15,643 at apogee. The orbit is inclined to the equator at an angle of 47.24° (an orbital inclination of 47° was intended) and the satellite's period of revolution is 118.3 minutes. The satellite is expected to remain in orbit for about one year.

Satellite Characteristics

The satellite, developed at NASA's Langley Research Center, has a diameter of 100 feet when inflated and a surface area of about 31,400 square feet. It is made of 82 tapered segments of Mylar polyester film 1/2-mil (1/2000-inch) thick, or about half the thickness of the cellophane on a cigarette package. The outside of the shell is covered with vapor-deposited aluminum less than 1/25,000-inch thick. The aluminum film can reflect over 98% of all radio waves

of frequencies up to 20,000 megacycles per second. In addition, this surface is highly reflective to light, facilitating optical tracking; it also exerts some control over the satellite's temperature.

The sphere was carried into orbit folded accordion-fashion inside a magnesium container 26.5 inches in diameter (Fig. 3). Before launch, both sphere and container were pumped almost entirely free of air in order to slow the sphere's inflation rate when orbit was achieved. After release from its container, the sphere first began to inflate gradually as the small amount of residual air left inside expanded. Further inflation was accomplished by the 30 pounds of sublimating powders inserted in the sphere before it was folded and placed in its container—ten pounds of benzoic acid continuing the expansion begun by the residual air, and the remaining 20 pounds of anthraquinone sustaining inflation until the sphere reached its full dimensions.

Anthraquinone was used because it has a very low vapor pressure, thus maintaining low internal pressure inside the sphere—about .00004 pounds per square inch. It was expected that the sphere would sustain many small punctures from cosmic dust and micrometeorites, permitting the gases to escape. However, the low internal pressure slows the leakage of gases from the satellite, thus maintaining its shape and increasing its life to the maximum possible length of time. Early in August, the satellite survived the Perseid meteor shower with no apparent serious damage.

Sunlight plays an important role in maintaining the sphere's shape, since the sublimating powders turn into gas at temperatures just above freezing, while the satellite temperature is well below freezing once out of the sunlight. In continuous sunlight, the temperature was expected to average about 240° F. Owing to the height of 1960 Iota 1's orbit and to its position relative to the Earth and sun, the satellite was in continuous sunlight for its first two weeks in orbit. After this, the relative positions changed and the sphere was at times in the Earth's shadow, causing its temperature to fall below freezing and any remaining gases to solidify. The experimenters were interested to learn if the satellite would re-inflate when once again in sunlight, and in what form. At the end of August, after increasing periods in the Earth's shadow, no change could be discovered in the sphere's size, shape, or ability to reflect radio signals. If it had not returned to its spherical shape, it would no longer have been useful for communications since signals would be reflected non-uniformly from a misshapen surface.

Two wafer-like transmitters for use as tracking beacons are attached to opposite sides of the sphere's equator. Each beacon is about 10 inches in diameter, 3/8-inch thick, and weights about 11 ounces. Each is equipped with 70 solar cells, five nickel-cadmium storage batteries, and a small whip antenna. Originally coiled into spiral grooves in each beacon, the antennas sprang perpendicularly outward from the sides of the sphere when it inflated.

The total weight of the satellite at launch was 167.4 pounds, broken down as follows: plastic sphere, 132 lbs; aluminum covering, 4 lbs; sublimating powder, 30 lbs; two tracking beacons, 1.4 lbs. The container that carried the folded sphere into orbit weighed 24 lbs, and the third-stage casing, in orbit with the sphere, weighs about 50 lbs minus propellant.

The Experiment and First Results

The primary purpose of the Echo experiment was to test the feasibility of using satellites as passive reflectors of radio and television signals for long-range transmissions. It has become increasingly apparent during the past few years that present communications lines are greatly overcrowded and barely able to keep up with demand, which, moreover, continues to grow. Among the efforts to meet this problem is experimentation with both "passive"

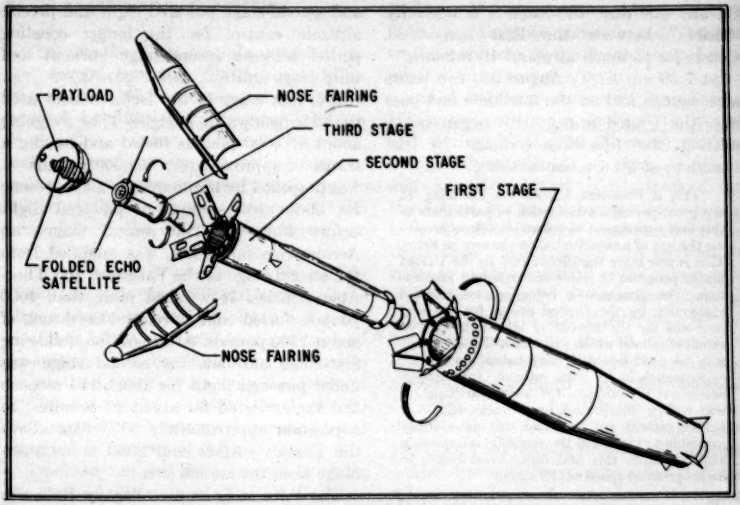

Fig. 3. *Delta Launch Vehicle and Payload Container With Folded Echo Satellite.*

and "active" satellite techniques. In the former, powerful signals are bounced off the reflective surface of a satellite; in the latter, weaker signals are received, amplified, and re-transmitted by radio equipment carried by the satellite.

The two primary stations taking part in the Echo experiment are the Bell Telephone Laboratories facility at Holmdel, New Jersey, and NASA Jet Propulsion Laboratory station at Goldstone, California. The aim was to bounce frequency-modulation voice transmission between the East and West Coasts of the United States off the highly reflective surface of the orbiting satellite.

BTL transmits on a frequency of 960 mc/sec for reception at Goldstone, and JPL is using a frequency of 2390 mc/sec for transmission to the Holmdel station. The Goldstone station uses two 85-foot-diameter paraboloid antennas, one a receiver and the other a transmitter. BTL is transmitting with a 60-foot dish and receiving with a specially constructed horn-reflector antenna. This 20 × 20 foot antenna, which is shaped like a steam-shovel scoop, is a recent development designed to reduce radio-noise interference.

The experiment proceeds as follows: First, orbital data is sent by Goddard Space Flight's Computing Center to both JPL and BTL for use in positioning the receiving and transmitting antennas. To set up the communications link, BTL then "illuminates" the sphere with a 960-mc/sec signal, which bounces off the satellite in all directions. A portion of this scattered energy is picked up by the Goldstone station, where the receiver is pointed toward the satellite. Goldstone then transmits a 2390-mc/sec signal to BTL, completing the communications link. Transmitting power at both stations averages about 10 kilowatts.

On any one pass, the satellite is mutually "visible" between the East and West Coasts for as much as about 16 minutes.

At 7:39 am EDT, August 12, two hours after launch and on the satellite's first pass over the United States, JPL began transmitting the following message by the President of the United States:

> "This is President Eisenhower speaking. It is a great personal satisfaction to participate in this first experiment in communications involving the use of a satellite balloon known as Echo. This is one more significant step in the United States program of space research and exploration. The program is being carried forward vigorously by the United States for peaceful purposes for the benefit of all mankind. The satellite balloon which has reflected these words may be used freely by any nation for similar experiments in its own interest. Information necessary to prepare for such participation was widely distributed some weeks ago. The United States will continue to make freely available to the world the scientific information acquired from this and other experiments in its program of space exploration."

The message was received clearly at the BTL Holmdel station beginning at 7:41, and continuous transmission over a period of about 14 minutes was also successfully received, with only a few interruptions when either the transmitter or receiver momentarily lost contact with the balloon.

A large number of other successful transmissions, from other stations and by other cooperating agencies, have since been made. These include two-way telephone conversations, "double hops" using an intermediate station to receive and re-transmit messages via the satellite, and transmission of a wirephoto image of the President.

Launch Vehicle

The new Delta vehicle used to put Echo 1 into orbit is an improved version of the three-stage Thor-Able satellite and space-probe booster. The Delta has a total height of 92 feet, a maximum diameter of eight feet, and a fueled weight of nearly 112,000 pounds. It is similar in configuration to the Thor-Able, but contains an improved auto-pilot and radio-guidance system for first- and second-stage powered flight and precise altitude control for the longer coasting period between second-stage burnout and third-stage ignition. (See Figure 3.)

The first stage of the Delta vehicle used in the launch was a Douglas Thor weighing about 100,000 pounds fueled and having a thrust of approximately 150,000 pounds. It was propelled by liquid oxygen and kerosene for about 160 seconds of powered flight before burnout. The second stage, an Aerojet-General rocket, was modified from the second stage of the Vanguard and Thor-Able vehicles. It weighed more than 4000 pounds fueled and developed a thrust of about 7500 pounds. After ignition, following first-stage burnout, the second stage was under powered flight for about 115 seconds and then coasted for about 15 minutes, to a position approximately 800 miles above the Earth's surface and 2300 miles down range from the launch site.

The third stage is an Allegany Ballistics Laboratory solid-propellent rocket weighing over 500 pounds fueled and developing about 3000 pounds of thrust. It was also used originally in the Vanguard and Thor-Able vehicles. In rapid sequence at the end of the second-stage coasting period, the third stage was "spun up" for stability to 120 revolutions per minute by small spin rockets, ignited, and separated from the second stage by explosive bolts. The third stage then provided power for about 40 seconds in order to achieve orbital velocity of about 16,000 miles per hour.

After third-stage burnout, de-spin rockets slowed the rotation and the empty casing was separated from the payload by a spring. In addition to being slowed slightly by the spring, the separated third-stage casing was tumbled by a small lateral rocket so that it would not interfere with the satellite. About two minutes after injection into orbit, an explosive in the form of a linear charge around the equator of the spherical payload container separated the two halves of the container and released the satellite, allowing it to expand to its full size.

Radio Equipment and Tracking

The two tracking beacons attached to the sphere transmit continuously at a frequency of 107.94 mc/sec and at a power level of 10 milliwatts. The solar cells are employed to recharge the beacons' batteries, and the transmitters are inter-connected so that if one is facing away from the sun it will nevertheless receive power from the solar cells of the other beacon as well as from its own.

The third stage of the launch vehicle (1960 Iota 2) is also equipped with a telemetry package to assist in determining the satellite's initial orbit and to signal payload separation from the third stage. This radio transmitted continuously on a frequency of 108.06 mc/sec at a power level of 300 milliwatts. It was battery powered and was expected to last two or three days.

Tracking for the Echo project is under the over-all direction of NASA's Goddard Space Flight Center. Tracking services are provided by BTL's station at Cape Canaveral; the Air Force radar test site at Trinidad, B. W. I.; JPL's Goldstone station in California; the Lincoln Laboratory Millstone Hill radar station, Massachusetts; NASA'S Minitrack network; and optical tracking stations of the Smithsonian Astrophysical Observatory.

Initial trajectory data were provided by BTL's guidance radar at Cape Canaveral and, during the launch, Minitrack stations at Fort Myers, Florida, Antigua, B. W. I., and Ascension Island (UK), tracked the third-stage beacon. After payload separation, Trinidad, which also tracked the third stage, "skin tracked" the payload by radar to observe inflation of the sphere.

Optical tracking, which also plays an important role in the experiment, is performed primarily by the 12 Baker-Nunn camera stations set up during the IGY and operated by the Smithsonian Astrophysical Laboratory, and by Moonwatch teams throughout the world. To the naked eye, 1960 Iota 1 has the brightness of a bright star.

The first positive confirmation that the sphere was in orbit came from Woomera, Australia, where the beacon signal was received and the satellite was observed visually on the first pass. The next was from Goldstone, which also both heard and saw the satellite.

World Days Report for IGC-1959

This report is one of a series issued periodically during and following the IGY. Earlier reports in the series appeared in *Bulletin Nos. 5, 10, 19, 23, 28,* and *31. Bulletin No. 23* contains a brief summary of solar flares, related geomagnetic activity, and World Warning Agency (AGIWARN) decisions during the IGY, and *Bulletin Nos. 28* and *31* review the first three-quarters of IGC-1959. The present report covers the fourth quarter of 1959 and summarizes the IGC-1959 period as a whole, comparing it with the IGY period and relating it to the current solar cycle.

Solar Flares, Geomagnetic Disturbances, and AGIWARN Decisions, Fourth Quarter, 1959

During the last quarter of 1959, the IGC World Warning Agency, operated by the National Bureau of Standards at Fort

Belvoir, Virginia, recorded 11 geomagnetic disturbances. Although this total was the same as that for the preceding quarter, the number of storms classified as severe declined from five to two.

Eight of the 11 disturbances were of the type common to the declining phase of the sunspot cycle, having longer duration than the typical solar-maximum storm but only minor-to-moderate severity. (Sunspot cycles average about 11 years from minimum to minimum, varying in length from 9 to 13 years; the present cycle began in 1954 and reached a maximum in 1957–58, during the IGY period.)

Most of the storms during the last quarter of 1959 tended to fit the weak 27-day recurring patterns of geomagnetic activity associated with the sun's 27-day rotation period. Others, which did not fit existing 27-day recurrence patterns, were thought to be the first disturbances of newly developing patterns. For about two years immediately following sunspot maxima, recurrent patterns are weak and difficult to discern; the tendency toward 27-day recurrence of geomagnetic storminess is expected to become stronger, however, as the next sunspot minimum is approached.

Only three of the magnetic storms recorded during the quarter could be associated with specific observable solar activity. Although not particularly severe, they generally exhibited the other characteristics of the typical solar-maximum storm—sudden beginning, short duration, and nearly simultaneous radio-propagation effects. Three of the five whole-day radio disturbances and 11 of the 34 six-hour disturbed-radio-quality figures observed during the quarter were associated with the sudden-commencement storms.

Solar activity was less evident than during the preceding quarter, with only two flares evaluated as Class 3 or greater in importance, compared with 14 in the third quarter. The two major flares occurred during the November 25–December 8 passage across the sun's disk of an outstandingly active center, which contained a giant sunspot group and was the source of at least 15 flares evaluated as Class 2 or greater. Though the region displayed activity of the type normally associated with severe radio and magnetic disturbance throughout its transit, such effects did not materialize.

The following is a list of major solar flares, geomagnetic disturbances, world-wide geophysical Alerts, and Special World Intervals (SWI) for the fourth quarter of 1959.

Oct	1	04xx	Magnetic storm begins
		1600	Alert issued*
	2	11xx**	Magnetic storm ends
	3	17xx	Severe magnetic storm begins
	4	1600	Alert issued; auroras expected
	7	13xx	Severe magnetic storm ends
	18	01xx	Magnetic storm begins
		1600	Alert issued
	19	14xx	Magnetic storm ends
	29	2347	Magnetic storm begins
	30	1600	Alert issued
Nov	5	16xx	Magnetic storm ends
	23	00xx	Magnetic storm begins
		1600	Alert issued
			SWI starts†
		21xx	Magnetic storm ends
	24		SWI finishes
	27	2350	Severe magnetic storm begins
	28	1600	Alert issued; auroras expected
			SWI starts
		2010	Class 3 flare; slow S-SWF††
		23xx	Severe magnetic storm ends
	29		SWI finishes
	30	07xx	Magnetic storm begins
		1600	Alert issued
			SWI starts
		1720	Class 3 flare; S-SWF††
Dec	2		SWI finishes
	4	06xx	Magnetic storm ends
	5	0659	Magnetic storm begins
			1600 Alert issued
	6	11xx	Magnetic storm ends
	13	17xx	Magnetic storm begins
	16	18xx	Magnetic storm ends
	23	1527	Magnetic storm begins
	24	14xx	Magnetic storm ends
	26	11xx	Magnetic storm begins
	27	1600	Alert issued
	30	21xx	Magnetic storm ends

Notes:

* No ending times for Alerts are issued, as was done during the IGY; this is now left to the discretion of individual observatories.

** "xx" indicates gradual beginning or ending of a disturbance, following the hour indicated, such that the precise moment could not be determined.

† SWI's, when warranted, start at the time the

associated Alert is issued; they finish at the end of the day indicated.

†† Slow S-SWF—slow short-wave fadeout (taking 5–15 minutes) and gradual recovery; S-SWF—sudden-wave fadeout and gradual recovery.

Summary for IGC-1959

During IGC-1959, AGIWARN recorded 39 geomagnetic disturbances. Regional Advance Geophysical Alerts were issued announcing 26 of these storms, and 31 were of sufficient severity to warrant the issuance of world-wide Geophysical Alerts. Only nine of the storms during IGC-59 can be classified as major disturbances, using a daily storm index of $A \geq 50$ as the criterion. SWI were declared in association with six of these. (The A-index measures geomagnetic activity on a linear scale ranging from 0 to 400; see *Bulletin No. 31* for a more detailed discussion.)

SWI's were in effect 14 days during IGC-59. Seven of these days were associated with the six major storms mentioned above; the other seven were distributed among the remaining 30 less-severe disturbances. Three of the nine major disturbances began gradually. The other six were of the sudden-commencement type associated with observable solar phenomena. Two of the three major disturbances for which no SWI were declared were of the gradual-beginning type.

IGC-1959 began less than a year after sunspot maximum and the smooth monthly sunspot number had dropped only about 12%. Thus, geomagnetic activity at the beginning of IGC-1959 was still comparable to that during the IGY. By the end of IGC-59, however, the smoothed monthly sunspot number showed a 36% decrease from the maximum and geomagnetic activity more typical of sunspot minimum had begun to occur.

The frequency of geomagnetic disturbances during IGC-1959 was essentially the same as during the IGY, but the storm characteristics exhibited marked change as the sunspot number dropped. Of the first 21 IGC-1959 disturbances, 17 began suddenly and, in most cases, were associated with important solar flares or other violent visible solar activity. Of the last 18 storms, only seven began suddenly. The remaining 11 storms began gradually and were generally longer but not as severe as the sudden-commencement disturbances. Many exhibited a cyclic pattern, tending to recur every 27 days.

The diminishing activity of the sunspot cycle as IGC-1959 progressed was not reflected by a corresponding decrease in the number of Advance Geophysical Alerts for solar flares from the beginning to the end. Of the 19 flare alerts issued in 1959, eight were in the first half of the year and 11 in the second half.

IGY Bibliographic Notes

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